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THE MOTTLING OR YELLOW STRIPE DISEASE OF SUGAR-CANE.

By JOHN A. STEVENSON.

INTRODUCTION.

The epidemic of cane disease which has prevailed in the Island through several seasons has continued with unabated severity. Not only has the disease not shown any decrease in virulence in the districts formerly reported as infected but has spread into new areas, and is here likewise causing heavy losses. It seems certain that the portions of the Island as yet free of infection will, before another has passed, fall prey to the ravages of this disease.

Studies as outlined in a previous report (31)[1] have been continued as vigorously as circumstances permitted, and it is felt that satisfactory progress has been made toward an understanding of the problems involved. It has been necessary to still further alter views previously held as to the nature of the disease involved. As a result of experimental and field data obtained it has become quite clear that mottling cannot be considered as a form of degeneration and that it is an infectious disease.

A complete discussion of all phases of the problem, covering the work of practically three seasons, follows in the body of this paper, and will form a final report by the writer on the mottling disease of cane.

[1] Figures in parenthesis refer to literature cited on p. 66.

NOTE.—Credit is due Mr. E. D. Colón, now Director of the Insular Experiment Station of the Department of Agriculture of Porto Rico; to Mr. R. C. Rose, formerly first assistant pathologist, and to Mr. Bernardo López, assistant, division of plant pathology and botany for assistance in the work of obtaining field data and other information. Favors extended by officials of the South Porto Rico Sugar Co. have aided in the prosecution of the work.

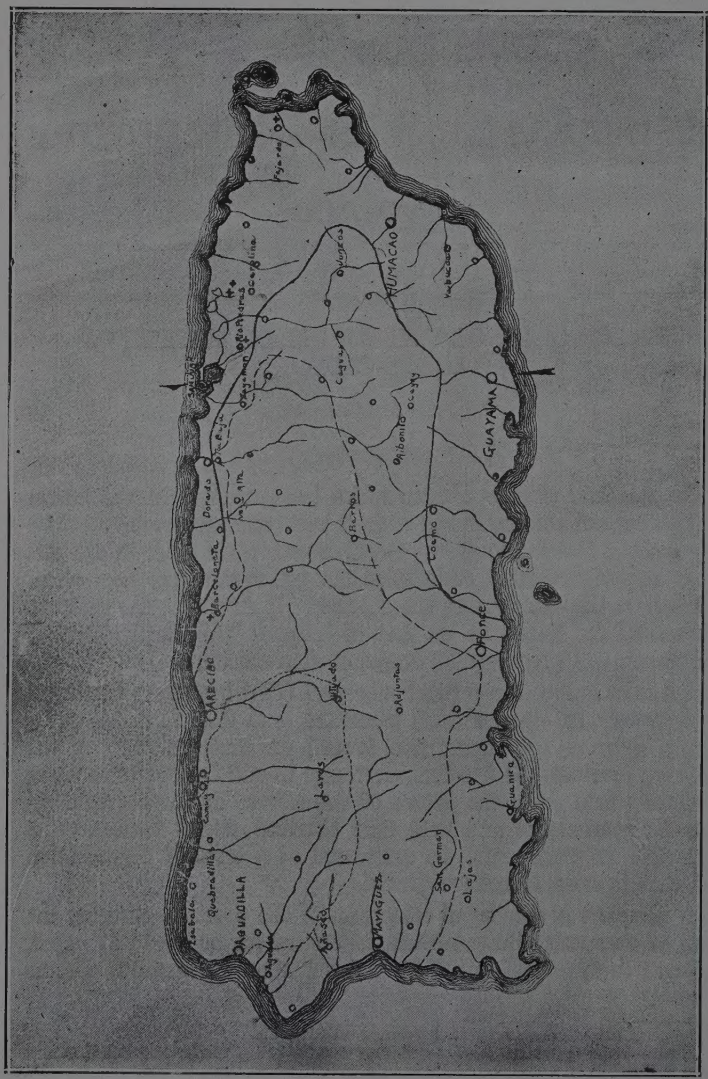

FIG. 1.—Sketch-map of Porto Rico, showing successive diseased areas.

NAME OF THE DISEASE.

Various names have been applied to this malady. It is universally known among the planters as *la enfermedad* (the disease) all other cane diseases of their experience sinking into insignificance in comparison with it. Of late it has also been called in popular accounts *mordida de perro.* The writer has referred to it at various times as the "new disease, the mottling disease, and cane canker," but considers the term mottling disease more nearly descriptive than any other, and therefore preferable. This name was definitely proposed in the 1916–17 report.

Cane canker is not considered suitable since the canker stage is not always present. Chlorosis, which might be used, and in fact was used to some extent, is pre-empted by a very different type of non-parasitic disease occurring in limited areas on the south coast. Prof. Earle (9) has recently used the term mosaic [1] which has nothing to recommend it in preference to mottling. Mr. Colón in the same paper refers to the disease as yellow-striping or *enfermedad de las rayas amarillas.* This is hardly suitable since it is not descriptive of the disease on the one hand and on the other will cause confusion with the natural phenomenon of yellow striping so common in certain varieties of cane, particularly the dark red, and which is a non-parasitic phenomenon of the class referred to by plant breeders as chimeras.

DISTRIBUTION.

The disease has made very definite and rapid progress during the time it has been under observation. At the end of the first season's studies as noted in the 1915–16 report (26), it had attacked the cane in the region bounded by Aguadilla to the west and a line from Utuado to Arecibo, or along the valley of the Arecibo River, on the east. Lack of time did not then permit the working out of more exact boundaries, particularly along the south and west.

The approximate extent of territory covered by the disease up to July 1, 1916, is shown by the dotted line on the map (Fig. 1). The area already covered at this time indicates that the disease had been active for some years at least, and it is not impossible that it had been present for a much longer time as a minor trouble in the upland fields beyond the coastal plain. Some planters have declared that the disease has been known to them for many years, and others are equally confident that it is an entirely new proposition. Be-

[1] A name suggested and used by Mr. F. S. Earle, Specialist on Cane Diseases, Insular Experiment Station, because it at once indicates what he believes it to be the nature and relationship of the disease.—EDITOR.

cause of the ease with which the mottling is confused with other cane diseases and abnormalities such as yellow spotting, chlorosis, striping, and others discussed further on in this paper, it is impossible to arrive at any conclusion, based on information obtainable to date, as to when it was first introduced to the Island.

During the remainder of 1916, and throughout the time since then the disease has made continuous and extremely rapid progress. The broken line on the map indicates the area covered up to the date of the last report (31) preceding the present one, as far as data was available.

It will be noted that it had by this time occupied at least half the extent of the Island, having advanced a considerable distance to the east, and reached a point south of San Germán on the west. In commenting on the spread of the disease for the 1916–17 season it was noted "that the trouble has been largely confined to the upper reaches of the river valleys, to small enclosed inland valleys, and practically to fields among the foothills. The broad stretches of the coastal plain, but little above sea level, are still free or comparatively free of disease. Near Arecibo many of the lowland fields show on the average one per cent of mottled stools, but farther east, in the lowlands of the Plazuela Sugar Company,[1] it was impossible to find a single diseased stool, although mottling commenced the instant the foot-hill formation began. This state of affairs was hardly to be expected, if the cause is parasitic, since these lowland fields are planted to susceptible varieties and form great continuous areas, often extending for miles in unbroken stretches."

This state of affairs has continued in large part to date, infection not being uniform and continuous in these lowland tracts. It has been possible in specific cases to trace the source of infection to use of diseased seed rather than to natural agencies where serious amounts of disease have been found.

At the present writing (November, 1918) the disease has covered over three-fourths of the Island as shown by the solid line on the map (Fig. 1). The disease-free area now includes only the cane-growing regions of the coast from San Juan to Fajardo, and those from Fajardo to the south as far as Central Fortuna.[2] To the west of San Juan the coastal area is comparatively free of mottling as far as inspections have been carried, but indications point to a serious outbreak here before another season has passed. Isolated infections

[1] These lowlands are at present infested also.—EDITOR.

[2] Outbreaks of mottling have been reported recently at various places between Central Fortuna, near Ponce and Central Lafayette, near Arroyo, as well as in the Fajardo and Naguabo districts.—EDITOR.

have been located at several points in the eastern sections, from which beyond much doubt the remainder of the territory will be speedily attacked. It is interesting to note that the inland valley districts of Caguas, Juncos, Cayey and Utuado are seriously infected, even though practically isolated. The cane fields around Utuado have been diseased for at least four seasons, but those of the other three districts had been free until within a year. This bears out the statement made in the previous report (31) concerning the manner of progress of the disease.

"In its eastward course the disease has apparently jumped from valley to valley, or has appeared spontaneously at many points some distance back from the ocean, rather than working along through the continuous coastal fields and then up each successive valley. It has almost universally evinced a marked preference for upland fields, in spite of the fact that they do not form the continuous areas so characteristic of the lowland country. Not only are these fields themselves broken up by the numerous small hills, but the many valleys large and small are separated by extensive ridges and chains of hills."

In the original center of the infection area from Arecibo to Aguadilla, the disease has continued severe where cane has been planted, but there was a general movement in this region to abandon cane in favor of tobacco and other minor crops.

The situation at Utuado remains unchanged with fifty to one hundred per cent of infection, and the same conditions prevail in the neighborhood of Adjuntas.

From Aguadilla southward there is probably not a field which will not show from one to fifty per cent of infection. Here again the disease was first noted and first caused serious loss in the uplands but has now spread throughout all fields. In fact reports from the Aguadilla-Aguada district (Central Coloso) were to the effect that there was less disease during the season just past in the uplands than in the lower lying fields. Such field observations as time permitted seemed to verify this conclusion, but it can doubtless be explained by the fact that the upland fields, after being abandoned to the disease the year before, were given thorough cultivation and replanted with selected seed, while the lowland fields were being ratooned.

The cane fields of the entire southwest section of the Island are in what might be termed the second phase of the disease in which a decrease in yield is becoming very apparent. A year ago only very slight infections were noted, less than one per cent in the aggre-

gate, and many fields were entirely free of mottling. During the past season practically every field has become infected to a varying extent, and there is every indication that serious losses will be sustained in the coming crop.

Along the south coast the disease has advanced to the east beyond Ponce as far as Fortuna. It is particularly serious in the neighborhood of Peñuelas to the west of that city, as well as in the cane growing sections immediately adjoining it.

There is every indication that in the coming season the disease will continue to a successful conclusion its conquest of the cane fields of the Island, since only a comparatively small section remains and this already has several known points of infection.

AMOUNT AND NATURE OF THE LOSSES.

It is difficult to arrive with any degree of accuracy at the losses sustained by the cane growers as a result of the ravages of this disease, because of the great variation in amount and severity of infection from field to field. In last year's report an estimate of $500,000 loss for the season was made and this was considered conservative.

A comparison of sugar statistics for two seasons past will give some measure of the loss sustained. The 1917 crop as reported by the Bureau of Property Taxes of the Treasury Department was 503,081 tons of sugar, while that of 1918 fell off to 453,795 tons. This shows a decrease of 49,286 tons with a value of over $5,000,000 figuring sugar at $5.27 per hundredweight, the average price for the season. Not all of this loss, however, can be charged to the mottling since the weather in certain sections and particularly in some where the disease had not penetrated, was such as to cause a heavy falling off in yield. A comparison of the output of the centrals (factories) of the Island for the two years makes it appear that at least half of this disease may be charged to the disease making the loss for 1918 $2,500,000.

Comparable results cannot be obtained by a study of the statistics for earlier years since economic conditions have been such as to cause great variation in the amount of cane planted, independent of natural factors. In the last two seasons, however, the area planted has been practically uniform except as influenced by the disease.

If to the figure $2,500,000, the estimated loss for 1918, there be added $500,000 for 1917, and the same amount for all previous years (but 1916 for the larger part), we reach a total of $3,500,000 loss to the sugar industry of Porto Rico to date.

The loss as heretofore has fallen heaviest on certain north coast mills. Several not before affected have suffered appreciably in the crop just past and there has been no improvement in the output of those which bore the brunt of the attack last year. One case in particular may be mentioned where the production for the year was only half that of the previous season, due without any question to the effects of mottling. Another central reported a loss of nearly eight thousand tons, again entirely chargeable to the same cause. At least ten other sugar companies have a falling off of from five hundred to three thousand tons each which can not be attributed to drought or environmental factors.

Many of the *colonos* (growers who sell their cane to the centrals) and more especially those in the Arecibo-Aguadilla region where the disease first attracted attention, have been forced out of cane growing and have taken up tobacco, or other less remunerative crops. Their number is rapidly increasing. The adjustment necessary to the growing of new crops entails no little loss under present economic conditions with greater liability of failure because of unfamiliarity with cultural conditions.

To turn to the nature of the losses incurred. As will be noted from the discussion under symptoms the losses result primarily from a decrease in tonnage. In the very early stages of infection it is not apparent to the observer that there is any reduction in yield or amount of sugar present in the juice. Exact experiments have not been carried out locally to test this point, but an experiment performed by Lyon (20) of the Hawaiian Sugar Planters' Experiment Station with a disease called by him yellow-striping, which is similar in nature to mottling, gives an exact idea of the reduction in tonnage and sugar content.

"The experiment, planted in eight 80-ft. rows was arranged as follows:

Rows 1 and 8, outside, blanket rows.
Rows 2, 4 and 6 cuttings from healthy canes.
Rows 3, 5 and 7 cuttings from canes having yellow stripe disease.

"Two cuttings of three eyes each were taken from the top of each stick. All of the cuttings were carefully inspected to see that each had three perfect eyes. Sixty cuttings, thirty top and thirty second, were planted in each row, the top and second cuttings being similarly placed in each row.

"The cuttings from sound and diseased canes sprouted equally well and gave what appeared to be a uniform stand of cane. Not

a single stick tasseled in the experiment during the winter of 1912–13, but most of them tasseled in November, 1913.

"The cane was cut during the last week in February, 1914, giving the following results:

"From healthy cuttings, rows 2, 4, and 6—

Healthy canes	430	weighing	3,991.0 lbs.
Diseased canes	81	weighing	693.5 lbs.
Undetermined canes	137	weighing	887.5 lbs.
Total millable canes	648	weighing	5,572.0 lbs.
Dead canes	187	weighing	553.5 lbs.

"From diseased cuttings, rows 3, 5, and 7—

Healthy canes	3	weighing	28.0 lbs.
Diseased canes	335	weighing	2,683.5 lbs.
Undetermined canes	75	weighing	387.5 lbs.
Total millable canes	432	weighing	3,099.0 lbs.
Dead canes	210	weighing	534.5 lbs.

"Juice samples were obtained by grinding the cane from corresponding sections in the centers of two rows. The analyses were as follows:

From healthy canes——Brix 20.3, sucrose 19.07, purity 93.9
From diseased canes——Brix 20.1, sucrose 19.11, purity 95.1

"The yields per acre computed from the above data would be:

Healthy canes	101.13 tons cane,	14.98 tons sugar.
Diseased canes	56.24 tons cane,	8.43 tons sugar.
Difference	44.89 tons cane,	6.55 tons sugar.

"When comparing these yields it should be noted that twelve per cent of the canes from healthy cuttings became diseased during their growth so that the yield from healthy cuttings was thereby somewhat reduced."

As the disease progresses and during the second year of its presence as a general rule, there is a very marked falling off in the yield, which may vary anywhere from twenty to one hundred per cent. From this stage on there is also an accompanying decrease in the amount of juice in the canes. The final stage in which no merchantable cane is produced and the field is abandoned may occur the second year, but more commonly during the third, or on the second ratoon. Hundreds of acres have reached this stage and thousands more are approaching it.

In the severely diseased stalks of this latter stage (those showing cankering and splitting) there is not only the reduction in size and

the dry pithy condition due to a lack of juice, but what juice is present is highly objectionable from the viewpoint of the mill. Several mills have reported a high and therefore undesirable glucose ratio with correspondingly low sucrose, but other tests have not substantiated this. The length of time between cutting and milling may well account for this in the instances reported, due to the cracked, cankered condition of the canes, which exposed the sugar containing tissues to the action of the air and fermenting organisms.

Some further data along this line will be found under the heading "Chemical tests of the juice."

RATE AND MANNER OF SPREAD.

The rate of spread in general as applied to the entire Island has already been given. To obtain a more detailed idea of the rate and manner of spread careful notes were kept on the progress of the disease in several fields near Río Piedras. As this was an isolated infection area, no other diseased cane having been found within at least ten miles until very recently, the data obtained illustrates the manner of spread from a single infection.

About 1915 a small planting (several rows) of Penang cane, the seed for which had been brought from near Aguadilla, was made as part of a variety experiment. The experiment after two seasons was transferred to another field with the exception of the Penang, which had practically died out. This condition had not been called to the writer's attention and it cannot be definitely stated that mottling was the cause of the trouble, although all evidence points to that conclusion. The field was not examined until after it had been plowed but several volunteer cane shoots, well marked with the disease, found some weeks later confirmed this opinion. Field men after having been shown characteristic specimens agreed that the disease had been present on the variety in question.

In the second field mottling was not noted until several months after planting, when infected stalks of B–3922 were found. As this variety had adjoined the Penang in the first test it seemed reasonable that a transfer had taken place at that point and that diseased seed had subsequently been planted in the second field. Infected stools were marked as they were found and their behavior during the season watched, stool to stool search being made at intervals. It was particularly desired to ascertain the age at which cane was susceptible to attack as well as the rapidity with which it spread from stool to stool.

FIG. 2.—Sketch-map of experimental field, illustrating manner and rate of spread of disease.

The following table gives the number of diseased stalks found in each stool throughout the season:

Table I.—Occurrence of Diseased Stalks.

Stool No.	DATE OF OBSERVATION						
	May 16	June 11	June 23	July 10	July 30	August 17	Sept. 20
1	3	3	3	3	3	4	4
2	7	8	8	8	6	5	4
3	12	12	13	13	13	10	10
4	1	1	1	1	1	1	1
5	2	3	3	3	3	3	3
6	2	3	3	2	2	2	2
7		1	1	3	3	3	3
8		13	13	11	10	8	8
9	5	5	4	3	3	3	3
10	5	5	5	2	2	1	2
11	2	2	1	2	2	2	2
12		1	10	6	6	6	6
13	5	6	7	5	6	6	6
14	1	1	1	1	1	1	1
15	10	11	11	7	7	6	5
16		6	6	4	4	4	3
17		6	6	5	4	4	4
18					1	1	1
19					3	4	5

It will be noted that there was comparatively little change, a number of weaker suppressed stalks dying, and a few additional ones developing the characteristic symptoms. As near as could be ascertained the mottled shoots in each stool arose from seedpieces other than those producing the normal shoots which predominated in nearly all the stools. Four seed pieces were planted in each hole, their combined stalks making up the stool.

Several other stools in adjoining varieties showed mottling during the season as noted on the chart. (Fig. 2.) The results obtained here, combined with a series of field observations, make it evident that the bulk of infection occurs in young plants.

At the end of the season all diseased stalks (none had shown cankering or other abnormalities beyond the leaf signs) were cut and destroyed. When the first ratoon shoots had reached approximately a foot in height, an attempt was made to eradicate the disease from the field, sufficient evidence having been obtained by that time of the ability of the disease to spread by other means than infected seed pieces. Six times during the season the entire field was gone over and all mottled canes dug out and destroyed. The first time over the field only stalks actually showing signs of the disease were removed with the corresponding rhizome and root portions. In every case, however, the disease reappeared in these stools necessitating further removal. This indicates that where eradication work

is attempted the entire stool must be removed even though but a portion of the stalks composing it show actual signs of mottling.

Wherever possible the stools were dug out carefully and search made for mottled and normal appearing shoots on the same rhizome. About twenty such cases were found in the course of the season and in each case a planting was made in the plant house of a portion of the apparently normal stalk. All of these, at a time varying from germination to several months later, produced leaves with the characteristic markings. It was very clear that once infection occurred the virus or infecting principle spread through all parts of the plant, even though it might not be apparent in all the stalks.

This eradication experiment will be further discussed under control measures.

OCCURRENCE OF THE DISEASE IN SANTO DOMINGO AND ELSEWHERE.

The presence of very pronounced mottling on recently germinated Crystallina cane, the seed for which had been imported from Santo Domingo, made it evident that the disease also occurred in that island. In order to investigate the nature of its behavior there, and with the hope of obtaining other information of value, this island was visited in the course of the year. The results of this trip as given in a report prepared at the time are as follows in so far as they apply to the mottling:

"The first case (mottling) was found in the fields in the vicinity of Higueral, north of La Romana. The disease was present in practically all fields varying in amount from a few scattered stools to as high as thirty per cent. The variety of cane was Crystallina. Symptoms of the disease, while characteristic, were limited to the mottling of the leaves. No evidences were seen of any stalks bearing the canker stage, in which the disease has proven so destructive in Porto Rico. Taken as a whole the cane in this district (Central Romana) appeared to be in fine condition, the presence of mottling having no appreciable effect on its growth.

"The disease was again encountered at Samaná in small plantings, the seed for which had been brought from San Pedro de Macorís in the year previous. This latter fact makes it quite evident that the disease also exists in the extensive plantings at Macorís although no opportunity was had for a personal examination at that place.

"Only very small plots of cane were found at San Francisco de Macorís and these were free of the disease. Similarly at Cabu-

llas, a point between San Francisco de Macorís and La Vega on the railroad, the cane was normal.

"Small plantings in the vicinity of La Vega were on the other hand typically diseased. No cane was seen in the Santiago section. It was not found feasible to visit the cane growing districts around Puerto Plata.

"In the neighborhood of Monte Cristi several small plots of cane were found, as well as one field of considerable size, which furnished cane for a small sugar and molasses mill. The cane in the latter field was heavily infected, as high as twenty per cent of the stools showing the typical markings on the leaves. As in the other instances no stalk cankers were seen or evidence of appreciable stunting of affected stools. Other cane plantings in this section were also affected, the seed having been brought in large part from the above mentioned field. One small patch was over fifty per cent infected. The cane was a mixture of the Rayada or striped and a white type, probably the Otaheite or Bourbon.

"These two varieties were also seen in the small plots examined in the Republic of Haiti between Dajabón, Santo Domingo, and Cap Haitian. They were, however, free of the mottling in so far as noted.

"On the return trip to the capital very characteristic examples of the disease were found in small patches of cane around dwellings at Bonao and along the trail in and out of the same *pueblo*.

"With the exception of the fields at La Romana no extensive plantings were seen on the trip until the capital was reached. East of Santo Domingo City there are two centrals, each with a large acreage of cane. Examinations were made here and the disease found in abundance and very typical in appearance. Small plots of cane to the westward of the city along the San Cristóbal road were unaffected.

"It thus appears that the mottling disease is widespread in Santo Domingo, occurring not only in the large commercial holdings but to a large extent throughout small scattered native patches. It seems reasonably certain that the disease has been present for many years, although there may have been recent reintroductions through some of the southern ports. The most interesting feature observed is the fact that while the leaf form of the disease—that is to say, the mottling—occurs very characteristically, it was not possible to find a single specimen showing the cankering and drying of the stalks.

"One can but conjecture as to the why of this state of affairs,

possibly the cane through generations of contact with the disease has reached a certain stage of immunity or Porto Rico has fallen heir to a more virulent strain. A more probable explanation lies in the practically virgin soils of Santo Domingo which tend to produce vigorous, more resistant canes. It is at least clear that Porto Rico need have no fear of further cane introductions from the neighboring island and on the other hand it may be found advisable to bring over the apparently resistant canes for further trial here.

"As far as the cane growers of Santo Domingo are concerned it does not at present appear that they need fear the mottling, but it would be well for them to become familiar with the disease and its latent possibilities for serious damage. Seed selection should be vigorously carried out to reduce the mottling to a minimum and any variety showing great susceptibility should be discarded."

One area of infection has been found on the Island of St. Croix, American Virgin Islands, by Dr. Longfield Smith, director of the experiment station. This case was very definitely known to be due to infected seed imported from Porto Rico. Prompt measures were taken to eradicate all diseased cane and it is hoped that there will be no spread of infection.

Correspondence[1] has failed to elicit further definite information as to occurrence. It seems probable at this writing that the disease is not present in any of the British West Indies, but that it is present in Cuba in much the same manner as it is in Santo Domingo. The relation of mottling with the yellow stripe disease of Java and Hawaii, and the distribution of the latter is discussed elsewhere in this paper.

VARIETIES ATTACKED.[1]

The list of varieties attacked is nearly as long as that of the varieties known to the Island. When the first investigations of mottling were made one variety was found subject to attack almost to the exclusion of all others. This was the common white cane (Otaheite or Bourbon) locally known as *Blanca*. It was this fact in large part which led to the conclusions given (26) in the first report on the situation. Very soon, however, the striped or *Kayada*

[1] Since the above was written information has been received from Mr. George L. Fawcett, plant pathologist of the Estación Experimental Agrícola, Tucuman, Argentine, to the effect that a disease occurs in the cane of that country which he believes to be similar to the mottling. From specimens and a photograph sent by him to the writer it has been possible to confirm his diagnosis. According to Mr. Fawcett the Argentine disease was formerly very prevalent on much grown varieties which have been replaced by others which are resistant to it, hence the disease is not causing appreciable loss at present. It is altogether probable that the importation of one or more of the varieties grown there will solve the problem for Porto Rico.

[1] See Bulletin 19—Insular Experiment Station (May 1919) "The Resistance of Cane Varieties to Yellow Stripe or the Mosaic Disease."—by F. S. Earle.—EDITOR.

fell prey and by the second season was no more resistant than the *Blanca* and has continued so since that time.

A third type grown at that time in the Arecibo district was a dark red hard variety, the so-called *Rayada morada* or *Sarangola,* which was introduced several decades ago to replace less resistant types during an epidemic or disease or insect visitation. During the first season it was markedly resistant, not a single authentic case of disease having been found upon it. Since then it has succumbed and while not so severely affected as the white and other varieties, the fact that it is susceptible combined with its poor milling qualities, make it an undesirable cane, and its use is no longer recommended.

A variety known as Penang grown to a limited extent in the vicinity of Aguadilla and said to have been introduced at the same time as the *Sarangola* has been practically exterminated, and may well have been the means of introducing the disease to the Island, since it is thought to have come from the eastern tropics. There is, however, no direct evidence to support this hypothesis. Further mention of the Penang is made under the discussion of an experiment in the rate and manner of spread of the disease.

Crystallina is the most extensively grown cane in the south and eastern sections of the Island, so that it is only recently that its resistance to the disease has come to a test. Unfortunately, because of its excellence as a commercial variety, it appears only too certain that it will prove no better than the other standard varieties. Seed of this variety was brought into the Arecibo region at considerable expense from what was at the time a disease-free area and planted in comparison with the *Rayada.* The plant crop (1919 season) exhibited enough mottled stools to make it evident that little hope could be had of its proving strongly resistant. As was noted this variety has been found infected in Santo Domingo and such is also the case to a very large extent in the newly infected areas of the south coast. Seed of this variety brought from Santo Domingo and planted near Río Piedras produced approximately ten per cent of mottled shoots upon germination.

Of the many foreign seedling varieties (for the most part those of Barbados and Demerara) experimented with by the division of agronomy of this station, all have shown infection but to a varying degree. Certain ones, as might be expected, have proven most susceptible in all localities, others appear to be fairly resistant as yet, while others vary considerably from one locality to another in their reaction to infection.

B–3922 upon which extensive observations have been made, has been most severely attacked in all places where tried. This has been the case not only on the well watered north coast soils, but under the drier south coast conditions as well. Further notes on this variety are given under another heading.

Yellow Caledonia has shown considerable variation in its susceptibility, certain fields very severely attacked having been seen and in contrast others nearly free have been inspected. This state of affairs, however is possibly to be explained by the presence or absence of the disease in the locality where the cane was under trial.

B–208 has with the exception of the *Blanca* suffered most severely of any of the kinds under observation, and it has been noted in this condition at Camuy, Aguada, Arecibo, and Río Piedras. B–3412 has likewise proven very susceptible when tried in the disease areas. D–117 has stood up as well as any of the better known seedlings, although cases have been reported where it had been nearly one hundred per cent diseased.

Other varieties found infected in varying degree have been B–109, B–4596 (very slight), B–3405, Sealey Seedling, B–6292, B–376, B–1809, D–109, B–6450, B–347, Egyptian 6VI6, 7VII7, and Javan seedlings Nos. 228, 234, and 856. A number of other Javan seedlings are known to be infected, but the numbers are not at hand. As far as known none of these canes as far as tried in Porto Rico have proven immune or even satisfactorily resistant.

Work with native seedlings, carried on by the two experiment stations and two of the larger sugar companies, has hardly progressed far enough to give any conclusive tests. All of the Mayagüez Federal Station seedlings seen (numbers one to five, were badly diseased wherever planted. Of the Guánica seedlings several have been seen diseased and a number of others are reported to be susceptible. From this same source there is also the report of seedlings, only a few months from seed (true seed, not seed pieces), showing typical symptoms.

Seedling work has been carried on most extensively at the Río Piedras station, the first plants having been started in 1912. Of the 1912 seedlings, which were the only ones ready for plantation tests, a number were sent to Arecibo and Aguadilla for trial. Practically all of these have shown slight infection as noted in the tables to follow. Some of them have also contracted the disease recently at Río Piedras.

Two additional varieties may be mentioned as being susceptible, the bamboo or *Bambú* a cane grown to some extent in the Arecibo

valley, which has followed the white (*Blanca*) in its lack of resistance and the Cavengerie, a dark red or wine colored cane, which ranks about with the *Rayada* in its behavior.

Variety tests were inaugurated by the station at a number of points in the disease-infected area in the hope of finding one or more types that would give satisfactory results in the presence of the disease. The results of these from the standpoint of tonnage and other agronomic factors have been reported by the plant breeder (8). Notes were taken on the percentage of diseased shoots showing in the various test plots as a measure of the susceptibility of the varieties involved. In some cases only one count was found possible during the season, but the data, though very incomplete, is given for what it may reveal concerning varietal resistance. In all of these experiments selected seed of the various varieties was sent out from disease-free plots at the experiment station. For the check plots the *Rayada* or striped variety was used, seed being obtained locally in each case. Most of it came from fields showing varying amounts of mottling but an effort was made to have healthy canes only cut for the purposes of the several experiments.

In the first experiment conducted near Aguada one-twentieth-acre plots were used the seedling types being alternated with the native *Rayada*. Only one count was made at the time the cane was about a foot high. The figures following indicate the number of mottled stools counted. Poor germination in half of the field will account for the small numbers in the latter portion of the table. Most of the varieties used were planted in triplicate.

Rayada 29	Rayada 12	Rayada 2
B–1809 20	B–1809 3	B–1809 7
Rayada 20	Rayada 14	Rayada 9
B–376 26	B–376 9	B–376 4
Rayada 19	Rayada 19	Rayada 4
B–6292 13	B–6292 11	B–6292 6
Rayada 20	Rayada 3	Rayada 2
S. Seed.[1] 38	S. Seed. 9	S. Seed. 7
Rayada 32	Rayada 10	Rayada 16
B–3405 6	B–3405 3	B–3405 6
Rayada 19	Rayada 2	Rayada 16
B–6450 7	B–6450 6	B–6450 1
Rayada 19	Rayada 5	Rayada 8
D–117 18	D–117 7	D–117 7
Rayada 17	Rayada 4	Rayada 9
D–109 0	D–109 5	D–109 1

[1] Sealey Seedling.

FIG. 3.—Leaf sections; normal at the right, mottled at the left.

Bases de Hojas Enfermas
Variedad Cristalina

Bases of Diseased Leaves.
Variety Crystalline

Rayada	9	Rayada	12	P. R.–292	0
P. R.–208	2	P. R.–260	1	Rayada	5
Rayada	3	Rayada	12	Y. Caled.[2]	2
P. R.–210	4	P. R.–272	2		

These figures give some indication of the relative behavior of the various varieties employed with respect to mottling since all were equally exposed to infection from the surrounding badly diseased fields. It would of course require further counts through the season and especially of the ratoons to be at all certain of the results.

Another plot in the same neighborhood planted the year before as a fertilizer experiment was also examined with the following results. These were tenth-acre plots.

Rayada	91	mottled stools.
D–109	20	mottled stools.
B–3412	99	mottled stools.
D–117	117	mottled stools.
B–4596	7	mottled stools. (4 doubtful).
B–109	58	mottled stools.
Rayada	112	mottled stools.

This more nearly indicates the comparative resistance of certain well-known varieties. Two which have been considered very valuable kinds and recommended for large scale planting here prove to be most susceptible, equalling or surpassing the *Rayada* used in check plots. These figures represent fifty to sixty per cent infections. The most promising canes were D–109 and B–4596 which have also given promise in other tests. It is of interest to note that B–4596 is a variety eliminated from the experiment station tests several years ago because of its great susceptibility to *Cytospora sacchari,* an imported disease which causes a stalk rot. This disease was not present on the cane in the experiment under discussion.

Near Vega Alta a variety experiment was gone over once early in the season with the following notes resulting. As usual, surrounding fields were diseased, in this instance between two and three per cent.

Rayada	9	Rayada	7
B–3405	3	Yellow Caledonia	0
B–109	3	B–4596	3
Rayada	19	Rayada	11
B–6450	1	B–6292	5
Crystallina	5		

An extensive test of varieties was put in in the Arecibo valley

[2] Yellow Caledonia.

again employing selected *Rayada* for the checks, the seed being secured from adjoining fields. Two counts at several months interval were possible here. The figures given indicate the number of stools showing one or more mottled stalks. The plots in this experiment averaged two hundred and ten stools each so that some idea may be gained of the rapidity with which the disease can infect from adjoining fields.

Variety	First examination	Second examination	Variety	First examination	Second examination
B-109	5	4	Rayada	16	18
B-4596	0	0	D-117	7	12
Rayada	3	8	D-109	2	3
B-3405	0	1	Rayada	27	29
S. Seed [1]	0	2	B-1809	6	7
Rayada	2	12	B-376	2	5
B-6292	2	6	Rayada	19	24
B-376	2	3	B-6292	7	8
Rayada	16	24	S. Seed [1]	1	2
B-1809	0	1	Rayada	3	5
D-109	1	0	B-3405	2	2
Rayada	12	21	B-4596	2	0
D-117	3	3	Rayada	10	14
B-6450	3	2	B-109	1	2
Rayada	14	33	B-6450	0	0
B-109	3	3	Rayada	3	7
B-4596	0	2	D-117	0	2
Rayada	1	9	P. R. 208	1	1
B-3405	3	8	Rayada	1	4
S. Seed [1]	5	7	P. R. 210	1	3
Rayada	7	13	P. R. 260	1	3
B-6292	12	13	Rayada	10	12
B-376	11	15	P. R. 272	4	2
Rayada	6	8	P. R. 292	2	4
B-1809	6	13	Rayada	3	3
B-6150	0	3	P. R. 317	0	0
			P. R. 318	0	2

[1] Sealey Seedling.

NOTE.—Several cases in which there was a reducción in number on the second count are due to the dying of the stools or shoots from diseased seed pieces in the interim.

B–4596 again gives considerable promise of being satisfactorily resistant as do several of the Porto Rico seedlings.

SYMPTOMS.[1]

The one marked and constant symptom of this disease, and the one by which it is easily recognized by any one who has occasion to visit diseased fields is the peculiar mottling of the leaves. It is readily distinguishable from any spotting or striping or other abnormality of cane leaves known to the writer. No trouble has ever been had in definitely ascertaining whether or not the disease was present except in a very few cases, where in new areas or new fields a part of a leaf or a few leaves only were found abnormal. A detailed comparison of the symptoms of mottling with those of other diseases with which it might be confused, is given further on.

[1] Adapted in large part from the 1916–17 report.

In fully expanded mottled leaves of the type commonly found, the backgrounds are green to yellow-green, depending upon the severity of the case. Two rather distinct types of discoloration have been noted but always grading into one another so that it is not considered that they are other than phases of the same phenomenon. Of these one is more common in early stages or light cases and has been especially noted in the unfolding leaves at the top of a stalk, sometimes changing to the second after a time. In this type the background or larger portion of the leaf-blade is a light, abnormal yellow-green and scattered about in it are areas of apparently normal color, "green islands," as it were. These spots are for the most part linear, but will vary from mere points to irregular blotches several centimeters long by a centimeter wide, always with a decided tendency to greater length than breadth. This phase is much more apt to be confused with certain other phenomena than the second, especially where the disease is making its first appearance in a new area.

The most usual phase of this disease seen, the one occurring over thousands of acres and in all varieties) is that in which the leaves are marked with numerous very light yellow-green to nearly white spots and short stripes. The background will vary in color from a normal green in plants but recently attacked to a yellow-green in more severe cases. The markings which produce the mottled effect are always much lighter in color, giving a very decided contrast. They are irregular in shape varying from almost invisible points to irregular spots two centimeters in their greatest dimension. For the most part they are linear, coalescing irregularly, and with indefinite margins. They will at times constitute fifty to sixty per cent or more of the total leaf surface.

The mid-rib remains to all external appearances normal. The leaf-sheaths present no abnormal signs, except a faint mottling in early stages of growth.

Mottled leaves do not die and fall away from the stalk any sooner than do normal ones, nor on the other hand is there any tendency to remain past the usual period of shedding. Varietal characteristics hold in this particular, irrespective of the presence or absence of mottling. There is no difference in the size of the leaves until the general stunting of the stools sets in in advance stages.

As a general rule the leaves are uniformly mottled, but in beginning cases examples are not uncommon in which a portion of a leaf only is affected. Such instances have been found where a stalk previously apparently normal commences to show mottling. The lower

leaves, anywhere from two to a dozen in number, will be to every appearance normal, then there will occur a leaf showing mottling for a few inches only at the base of the blade, which in turn will be succeeded by several others above affected from a half to two-thirds their length. All above these transtional leaves will be completely mottled. Occasionally one half of a leaf may be affected further than the other. The reverse condition of normal appearing leaves above mottled ones has not been observed. Through the season there may be in this manner a gradual increase in the number of stalks infected or at least in the number showing visible signs.

The disease follows what is approximately a three year course.[1] In the first year of its presence isolated stools only will show discoloration, scattered irregularly over the field and often composing less than one per cent of the total. One to five per cent infected is the common condition found in what is considered the first stage. At this time the only symptoms will be the mottling of the leaves above described. Often the first phase only will be present, or where the second also occurs the background will still be dark green. In a given stool the number of stalks showing mottling may vary from one to all, two or three, however, being a very common number. This in many cases merely means that the shoots from one seed piece only are infected (a number of seed pieces, usually four, are planted in each hole and the shoots from these form the stool). It is easy enough, however, to find shoots from a single seed-piece only part of which are mottled.

At this point in the progress of the disease since no other symptoms than the mottling will be found externally or internally, it is impossible after the leaves are removed to distinguish normal from abnormal cane. The internodes are sometimes somewhat shrunken, but the only sure test is to plant portions of suspected stalks and observe the leaves of the new shoots.

In the second year at the usual rate of procedure a very much larger percentage of infection is present. As far as it has been possible to ascertain, this includes all stools which showed mottling the year before, as well as a varying number of those that had been, when the first crop was cut, apparently normal. At this stage, in addition to the mottling, there may be a dwarfing of the stools and the canker stage may be present, depending somewhat upon the variety and possibly other conditions. The dwarfing may be sufficient to cause a loss in yield of from ten to sixty per cent. There is quite

[1] Other observers do not entertain this opinion as to a three year course.—EDITOR.

a decided shrinking of the internodes whether the stools are stunted or not.

The crop in the third year (second ratoon) is practically a total loss at the usual rate of progress.[1] This is due to the combined effect of dwarfed stools producing very short lengths of merchantable cane and the dry pithy nature of the stalks themselves, due to cankers, cracks, and lack of juice.

There have, of course, been considerable variations from this three-year sequence, depending upon varieties and other circumstances, but it holds to a very large extent.

A second very marked sign is what has commonly been referred to as the canker stage. This occurs more severely on certain varieties than on others, and similarly appears on certain ones before it does on others in point of time. The soft white canes, the Otaheite and Bamboo for instance, are peculiarly subject to it, fields of these varieties often entering this stage in the second year. The *Rayada* and other hardier canes show less of this phase of the disease as a rule, but fields do occur in abundance where these canes are seriously cankered and rendered absolutely worthless.

The cankering is plainly an advanced symptom, since a stool may show mottling through two seasons before it appears, and in one variety (*Sarangola*) only a very little has been noted as yet. The stem lesions or cankers originate and can be found on the internodes before the leaf-sheaths have loosened. At this period the lesions are first noted, as somewhat shrunken areas with a water-soaked appearance, soon becoming medium brown in color, and oval to linear, often irregular, in shape. With the falling of the leaf they pass through various shades of brown and finally to an ashen or dull gray color being still sunken, linear, and often coalescing to form large irregular areas more or less completely covering the entire internode. On the other hand, they may be limited to a few only on each internode. The margins of the lesions are quite distinct. They do not pass from one internode to another, the nodal regions forming a sharp line of demarcation.

Penetration of the tissues is never very deep, hardly more than from one to two milimeters at best, and is often limited to a few layers of cells only. The affected tissues are red but not different in shade or other characteristics from similar effects produced by other causes. There are no other internal symptoms except as noted below.

[1] Mr. Childs, manager of Central Los Caños, has data that show that five-year ratoons that had been infected for several years have produced as high as 25 tons per acre.—EDITOR.

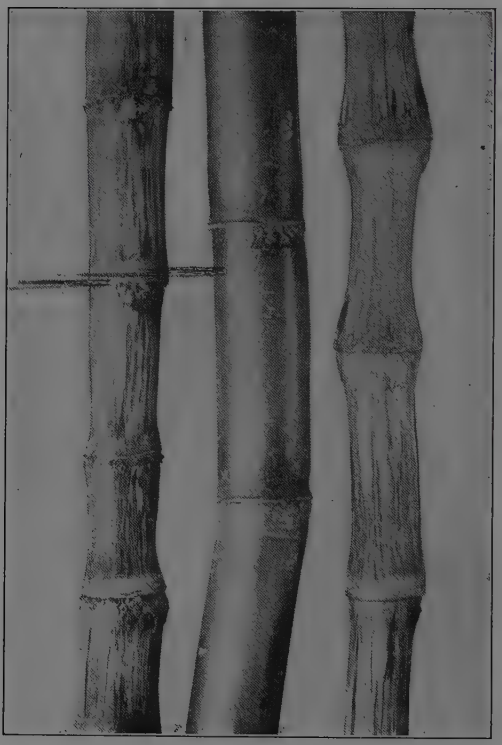

FIG. 4.—Cane stalks; normal in the center, cankered at the sides.

Cracking very often accompanies the cankering, and along these openings the same reddening of the tissues occurs, but it is of the same nature and extent as occurs in splitting of normal cane. Cracking is by no means an uncommon phenomenon; some varieties, and especially large stalks, being very subject to it. For this reason no special significance is attached to it as it occurs in connection with the cankers, other than to consider it a result of drying of the stalks, quite to be expected.

In addition to the stunting or dwarfing of the stools, there is a shrinking of the internodes of the individual stalks. This is especially pronounced in what might be termed third phase cases, or those in the last stages of the disease. Such stalks are almost completely lacking in juice, the limited amount of pith tissue formed being of a rubbery consistency. Where the trouble is not so far advanced the lesions may be present to a greater or less extent without an appreciable shrinkage of the internodes.

One peculiar circumstance that has been often noted in fields in approximately the second phase of the disease has been the finding of stalks showing only part of the internodes cankered. For instance, the lower five or six would be apparently normal and all above cankered and shrunken, or the lower internodes normal with five or six above cankered, and the balance above again apparently healthy. As an extreme case there may be noted a stalk of *Rayada* found above Arecibo, the condition of the internodes of which, proceeding from bottom to top, was recorded as follows: Four normal, five shrunken and cankered, four normal, five shrunken and cankered, top joints to all appearances normal. This sequence is undoubtedly due to an alteration of wet and dry periods.

In every case examined canes showing cankers, even if of one internode only, have also been found to have all the leaves mottled. On the contrary it has been very common to observe field after field showing mottled leaves in abundance but with no stalk cankers present.

There have been reports of apparent recovery from the mottling condition, but it has not been possible to investigate any such cases and they are considered very doubtful at best.

A rotting of the bud is never a sign of this disease and such limited cases as do occur can always be attributed to *Diatraea* or other agencies independent of mottling.

Nothing abnormal has been found in so far as the roots are concerned. As would be expected with cane growing under the conditions which have prevailed in the infected territory, there can always

be found great numbers of dead roots, but no more than in normal cane growing in the same region. The presence of one or more root fungi, of course, often complicated diagnosis, a point discussed under another heading.

Cuttings of normal and mottled cane (B–3922) taken from the same relative parts of the stalks and as nearly equal in size and age as possible were placed in standard nutrient solution. Watch was kept on root development over a period of several weeks or until the cultures were overgrown by molds. At no time was there any observable difference between the two lots.

A series of these cane cuttings were planted in the green house and one of each (normal and diseased) dug up carefully at intervals of a week, beginning as soon as the first shoots broke through the soil. As in the preceding experiment it was not possible to find any differences worthy of note.

It is not believed that there is any noticeable loss in germinating power of seed from affected stalks except those in advanced stages. Nothing of this nature has been noted in the planting tests nor has it been reported or observed in the field, although very little seed visibly infected has been planted, at least in the last year or two.

The symptoms of the mottling disease in brief may be said to be a mottling of the leaves, with no other observable change in the plant at first followed, generally in the first or second ratoons, by a dwarfing of the plant, the presence of cankers or lesions on the stalks, and a decrease in the amount of juice.

OTHER HOSTS.

Constant search has been made for other host pests since the finding of any such might well shed light on the origin of the disease, or make possible the obtaining of other valuable data. Grasses growing in and about cane fields have been particularly watched with this object in view. A number of specimens, for the most part *malojillo* (*Panicum barbinode*, Para grass), were found or sent in by correspondents showing varying amounts of chlorosis. These plants were set out in the plant house and grown for observation. The resulting new growth in all cases was entirely normal indicating that the clorotic condition observed in the field was physiological in nature.

Lyon[1] states that corn (*Zea mays*) is very subject to an infectious chlorosis in Hawaii, closely resembling if not identical with what he designates as "yellow striping" of cane. This condition has

[1] Unpublished note.

not been noted as yet in Porto Rico. Longitudinal white stripes of varying width are common on the leaves of the corn here, as well as on certain cane varieties as noted hereafter. They are doubtless of the nature of color chimeras and are therefore of more interest to the plant breeder than the plant pathologist.

The search for other host plants should be continued in order to thoroughly examine into the possibility of the theory advanced by some that the disease has originated on wild grasses in the upland districts and spread from these to the cane.

RELATION OF ENVIRONMENTAL AND CULTURAL FACTORS.

The field survey.

With the aim of inquiring into all possible conditions which might influence the disease directly or indirectly, or even be of a causal nature, various environmental and cultural factors have been studied both in field trips and in plant house experiments.

Throughout the course of the studies a large number of field trips to all parts of the Island and of course to affected districts in particular were made. In addition to those made by the writer, assistants in the division of plant pathology have also aided in this phase of the work, and results here recorded include information based on their reports as well as upon information obtained by correspondence and conversations with other members of the station staff, cane growers, and others interested.

It was realized, however, that while many facts were being obtained in this way, it was desirable to have data in greater detail, and in more orderly arrangement than the above methods permitted. Accordingly a form embodying the points upon which information was desirable was drawn up. The plan was to send out field agents to cover the entire Island as rapidly as possible, one of the forms being filled out for each field visited. This work was well under way before the writer left the Island and had advanced far enough to demonstrate its value. The outline used in this survey is as follows:

FIELD SURVEY—CANE DISEASES.

Field No._____
Acreage _____

Date_____
1. Location_____
2. Type of soil_____
3. Nature of terrain_____
4. Variety_____

6. History of the field:
   (*a*) Plant---------- Ratoon----------
   (*b*) Previous crops----------
   (*c*) Years in cane---------- (*d*) Rotation ----------
6. Percentage of stools showing mottling----------
   (If more than one variety present, give percentages for each.)
   (*a*) Percentage showing cankered stalks----------
7. When did disease first appear----------
8. Source of seed---------- Did field show disease?----------
9. Cultivation practices.
   Lime ----------
   Fertilizer ----------
   Extent of plowing, harrowing----------
   Seed selection ----------
   Seed treatment ----------
   Irrigation or drainage----------
   Subsequent cultivation ----------
   Hoed or cultivated----------
   Disposal of trash----------
10. Other diseases present: Miscellaneous----------
   Odontia---------- Sclerotium ----------
   Himantia ---------- Cercospora ----------
   Rind disease---------- Leaf spots ----------
   Red rot---------- Red striping ----------
11. Insects:
   Diatraea---------- White grub ----------
   Pseudococcus---------- Miscellaneous----------
12. Remarks----------

The aim of this outline was several fold, the data to be of use not only to pathological workers but to the entomologists and agronomists as well. It was designed to provide in convenient form the character of cultural practices, the nature of the soil, the history of the occurrence of the disease, and any other information obtainable as to presence of other diseases or injurious insects. Not only was it expected to prove of value in the mottling studies but to serve as a guide in other sugar-cane investigations.

In the following table is given the salient features of a survey of a considerable portion of the sugar-growing lands of the lower Arecibo valley in so far as they apply to mottling in which these forms were used. This work was performed in the summer of 1917 by Mr. E. D. Colón.

Table II.—Results of Field Survey in the Arecibo Valley.

Field No.	Area [1]	Soil	Variety	Years in cane	No. of crops	Disease appeared	% of disease	Remarks
1.....	296	Silt loam	Rayada	20	Mixed plant and ratoon	1914 (?)	80-95	Disease worse near water courses
2.....	12	Heavy loan	Rayada	4-5	Plant cane.....	1917	7	Good cultivation
3.....	15	Sandy loan	Rayada	30	First ratoon.....	1916	1	Good cultivation
4.....	19	Clay	Rayada	11	About third ratoon	1916	47	Fair cultivation; Fertilizer applied
5.....	28	Gravelly loam...	Rayada	11	Third ratoon	1916	50	Good cultivation
6.....	10	Gravel.....	Rayada	11	Fourth ratoon ...	1917	10	Good cultivation
7.....	56	Gravel loam.....	Rayada	3	Third ratoon	1917	15	Good cultivation
8.....	38	Sandy loam.....	Rayada	20-25	Plant cane.....	1917	5	Good cultivation
9.....	?	Sandy loam.....	Rayada	20	First ratoon.....	1917	1	Good cultivation
10.....	12	Sandy loam.....	D-117 B-208 Rayada...	20	Plant cane.....	1917	17	Seed from Experiment Station; Good cultivation
11.....	¼	Sandy loam.....	B-208.....	New land	Plant cane.....	(?)	3	Seed from Experiment Station; Good cultivation
12.....	6	Loam	Rayada	19	Plant cane.....	1917	5	Seed from Los Caños
13.....	2	Loam	D-117.....	8-9	Plant cane.....	(?)	4	Seed from Experiment Station
14	9	Loam	Crystallina.....	19	Plant cane.....	1917	0	Seed from Experiment Station
15	9	Sandy loam	Rayada	12	First ratoon.....	1917	2½	Good cultivation
16.....	23	Sandy to clay	Rayada	2	First ratoon.....	1916	½	Good cultivation
17	73	Sobre-vega.....	Rayada	12	Fourth ratoon...	1917	2-15	Good cultivation
18	93	Silt loam	Rayada	12	Third ratoon.....	1917	3	Good cultivation
19.....	11	Clay loam.....	Rayada	12	Fourth ratoon...	1917	Trace	Good cultivation
20	4	Gravelly loam ...	Rayada	12	Plant cane.....	1917	10	Good cultivation
21.....	210	Silt loam	Rayada	20	Third ratoon	1916	Trace	Good cultivation
22.....	102	Silt loam	Rayada	25-30	Plant cane.....	1917	10	Good cultivation
23	85	Silt loam	Rayada	7-8	Plant cane.....	1917	2-3	Good cultivation
24	14	Sandy loam	Rayada	?	Fourth ratoon...	1917	1	Good cultivation
25.....	9	Not given.....	Rayada	?	First ratoon	1917	1	Good cultivation
26	400	Sandy to loan....	Rayada	17	Ratoon replanted	1916	1-2	Good cultivation
27.....	600	Silt loam	Rayada	30	Ratoon replanted	1916	1-5	Good cultivation
28.....	400	Silt loam	Rayada	30 +	Ratoon replanted	1916	1-2	Good cultivation

[1] Area in *cuerdas*. *Cuerda* = 1 acre approximately.

A study of the data here presented bears out statements to be enlarged upon further on that soil, variety, years in cane, and other cultural matters have no direct bearing on the disease.

A similar survey was conducted in the Cayey district, an enclosed valley in the interior of the Island, which has been free of disease until comparatively recently. Some two thousand acres in six *barrios* were gone over here by Mr. Juan Simons, Deputy Agricultural Inspector.

A table from his field notes has not been prepared because of its similarity in salient features to the one already given; but his conclusions, adapted from his field report, are as follows:

"In all fields inspected the presence of the mottling disease of cane was noted. The infection varied from three to four per cent in the least diseased fields to sixty per cent or over in the most severe cases, with an average of ten to fifteen per cent.

"It is to be especially noted that plant canes, with three or four exceptions in *barrios* Beatriz and Vegas which had an average of six per cent infection, were as heavily attacked as ratoon canes.

"Ratoon cane with rare exceptions was generally severely attacked by this disease, having in almost all cases more than twenty per cent of mottled stools. In *barrio* Rincón for instance there was an area of more than two hundred and seventy-five acres of ratoons with an average of sixty per cent of mottled stools. Canes from these fields are being used for seed purposes in the new plantations which, of course, means the dissemination of the disease, and hence the high per cent of infection in plant cane.

"The soils in this region are for the most part of heavy clay, but are usually well drained. The fields are mostly hilly or rolling although there are great extensions of plains, but in no case was it noticed that the disease favored any particular class of soil or terrain, being found in equal intensity on hills and lowlands. In general the mottling disease is widely spread throughout the cane region of Cayey."

This will suffice to give an idea of the scope and purpose of the field survey. Most interesting data should result from the complete reports. As these records are made for individual fields, the location and name or number of each field being recorded, it will be possible in selected localities to make a second survey and so obtain information as to the course and behavior of the disease from season to season.

Cultural factors.

Because of the very great importance of cultural methods in their relation to most other cane diseases than the mottling, much attention has been given them throughout the course of these investigations. The cane troubles known as root disease and deterioration are so prevalent on the Island, and so widespread, that too much cannot be said as to the value, and, in fact, the necessity, of proper methods of cultivation, using the word cultivation in the broad sense, even though as is now apparent cultural factors do not in themselves serve to influence mottling.

The reiteration of these recommendations in various publications during the time the disease has been under study, as well as the earnest effort of the various sugar companies and growers to do everything possible to combat the mottling disease, have resulted in a thorough trial of all possibilities in this direction. The results will be briefly summed up below.

Deep plowing has been carried out in a number of localities both by means of steam plows and by tractors which are now well established on the Island. In some places at least, where the disease was present in disastrous amounts the fields been prepared for planting were plowed five and six times. Sufficient fields have been examined which had had excellent cultivation including a number of deep plowings to make it evident that such work was without any practical results as far as control was concerned. As much disease would be present, other conditions being equal, as where shallow holes only were made by hoes and no subsequent cultivation given. There would, of course, be an increased yield and relative freedom from other diseases.

Effect of fertilizers.

Great attention has been paid to the matter of fertilizers. Of recent years it had been found profitable on practically all the cane lands of the Island to apply chemical fertilizers. With the breaking out of the European war the supply was interfered with, certain ingredients becoming unobtainable, and even those available were very high priced. Many growers were inclined to place the blame for the poor condition of the cane on the lack of fertilizer, and they were doubtless correct in so far as yield and other factors, with the exception of mottling, were concerned.

The Insular Experiment Station has conducted over several years a number of very careful fertilizer experiments in various parts of the Island, and more especially in the western portions. Results

of these all appear in the annual reports of the station, and while they show clearly the value of fertilizers, often resulting in as high as fifty per cent gain in yields, there has never been the slightest evidence that there was any effect in controlling, or even in checking, mottling. This has been borne out by fertilizer experiments conducted by some of the sugar companies themselves. The following paragraph taken from a report prepared by Mr. Bourne in charge of experimental work for the South Porto Rico Sugar Company is representative of these tests.

"*Tablón* 7, in addition to its thorough tilling had a fairly good dressing of cow peas. In December 1917, sulphate of ammonia was applied at the rate of 300 pounds per acre to the 7.5 acres of B–3922 in *Tablón* 7. This part of the field was most affected and the sulphate of ammonia was applied to see if it would help to throw off the disease or turn the foliage greener. No change for the better, however, could be seen except that it caused a slight stimulation in its general growth.

"About the same time an experiment was conducted in triplicate plots in *Tablón* 9 with sulphate of ammonia, lime and filter press cake (*cachaza*). The sulphate of ammonia was applied at the rate of 540 pounds per acre, lime at the rate of two tons per acre, and the *cachaza* at the rate of thirty and sixty tons per acre. Check plots were left without any treatment, and up to the present there is no noticeable difference in any of the treated plots to those not treated."

To test the matter under more nearly controlled conditions an experiment was laid out in the plant house. Two-eyed cuttings of the variety B–3922 as nearly comparable as possible were used, ten each of normal and diseased being planted, and each in a separate container. After germination fertilizer of a standard 12–6 formula (twelve units of nitrogen and six of phosphate, potash not being obtainable nor for that matter necessary) was applied as follows: Four ounces to each of four cans, two ounces to each of four cans, leaving two without any applications as checks. Two to four ounces is the usual amount applied per stool in field practice. No effects were seen at any time, other than the slightly better growth of normal cane.

Claims were made that sodium nitrate would "cure" the disease and experiments were in order to prove or disprove this claim. Again using potted cane in the plant house, two ounces of sodium nitrate were applied to each of four cans, and four ounces to each of four, leaving two cans in the row of ten as checks. At the time

of application the canes in all ten cans had reached a height of about two feet and all were typically mottled. The four-ounce application was sufficiently strong to cause the death of the plants to which it was applied. In the case of the two-ounce doses there was a deepening of the green color of the leaves which somewhat obscured the mottling, but otherwise there was no change, and certainly no cure in any sense of the word. It was doubtless this effect, seen without careful examination, that led to the statement made. Where the cane had been killed, replantings of diseased two-eyed seed pieces of B–3922 were made. These suffered the same fate ultimately as their predecessors, showing mottling, however, as long as they were alive. Field tests in various localities have given the same results.

Liming.

Great hopes were at one time entertained as to benefits to be had from liming. As with other possibilities trials were made under varying conditions but with negative results as far as mottling was concerned. In following out this proposition several limed fields in the western section of the Island were very carefully gone over. Moreover a plant house experiment was set up and only served to make the negative results more evident. In this experiment cuttings of the same kind as used in other plant house tests were employed. Ten pots of mottled cane were assigned to this test, two serving as checks, two with a half ounce of air-slacked lime, four with one ounce, and two with two ounces. Lime is of value only in so far as it increases yields.

Ground or powdered limestone has been reported as a certain cure and is said to have been tried out by a number of growers but there does not seem to be any general movement to apply this material. The writer has not been able to locate any fields where it had been applied successfully. As a fertilizing agent it would be of somewhat less value than slacked lime because of its limited availability.

Seed treatment.

Seed treatment at the time of planting has been advocated as a preventive measure for the pineapple disease or black rot (*Thielaviopsis paradoxa*) and has been generally adopted for this purpose. In all publications on the subject it has been clearly stated that the dipping or soaking of cane seed in Bordeaux mixture was not effective for the control of any other disease than the pineapple disease. In spite of this warning, however, Bordeaux treatment has been repeatedly tried in the hope of checking the mottling, and of course

with absolutely negative results. At no time after the infectious nature of the disease became apparent was dipping recommended.

No direct experiments were performed, the experiences of the growers being sufficient, but it may be noted that of several hundred diseased cuttings planted in the green house experiments all were soaked in strong Bordeaux mixture for at least fifteen minutes and without exception all produced mottling shoots.

Ratooning.

In comparison with Santo Domingo and Cuba very limited ratoon crops are possible in Porto Rico, and in fact in large portions of the south coast it is the custom to replant every year. As a general rule not over two ratoon crops are obtained although there are exceptional cases where as high as fifteen or twenty crops have been obtained. In such cases, however, much replanting is necessary every year. In a disease of the nature of mottling there is an accumulative effect which, as has already been pointed out, proves disastrous in the third year or second ratoon in the usual course of events in Porto Rico. Where the disease has gained considerable headway in a given field no further attempt should be made to obtain a ratoon crop but the whole should be plowed up as soon as possible after cutting.

Drainage and irrigation.

These two points while of the very greatest importance in any consideration of root disease, deterioration, or similar cane troubles, do not seem to have the slightest connection with mottling. The results of field observations combined with the data of the field survey fail to indicate any such relation. All types of fields are invaded alike.

Disposition of trash.

This phase of field practice, discussed at some length in an earlier report (26) is now seen to have little effect on the mottling. The stand taken in that report is not receded from in so far as it applies to cane growing independent of the disease. Burning of the trash is a most objectionable practice and every effort should be made to conserve it for the benefits to be derived from its presence on the land. There will be an indirect benefit, even in the disease situation, since proper handling of the trash makes for increased yield which will serve to counterbalance in some measure losses from the disease. As far as the results of the field survey have been examined there is no evidence that burning or non-burning of trash has had any direct influence on the disease.

FIG. 5.—Planthouse, north-side view, Insular Experiment Station.

Effect of soils.

As with the preceding topics negative results only can be reported concerning the relation of different soil types. This was a point given consideration in the field survey and, as noted in the discussion under that heading, it was impossible to detect any effect of the different soils on prevalence or absence of the disease. A glance at the table on page — will show that the cane on practically every class of soil varying from sand to the heavy red clay of the uplands is subject to attack.

In tests carried out in the plant house three types of soil were used, a pure white sand such as was being used for building operations, the black loam used in propagating work at the station, and a red clay subsoil. Cuttings used were from diseased and normal stalks of B–3922, cut to two buds or internodes per piece, and all dipped in Bordeaux mixture fifteen minutes before planting. There was never at any time any effects as far as absence, presence, or relative virulence of mottling was concerned. Diseased cuttings produced diseased stalks, the normal cuttings healthy stalks, and there were no changes throughout the season. There was of course great variation in the amount of growth, plants in clay and sand thriving poorly except when aided by chemical fertilizer.

A very striking illustration of the conclusion that the nature of the soil has no effect on the disease is furnished by the field in which the disease first appeared near Río Piedras. The soil was very fertile, had not been planted to cane for many years and gave what was probably the highest yield of any field on the north coast.

Rainfall and soil moisture.

Of the considerable number of theories suggested, the one which warrants most serious consideration is the relation of the weather, and more particularly the periods of drouth to this epidemic. The records of the United States Weather Bureau have been studied in an endeavor to correlate the rainfall, or perhaps the lack of rainfall, with the inception and spread of the mottling, but this has not not been very successful. The greatest difficulty has been in the nature of the rainfall of Porto Rico, which in large part comes in the form of numerous local showers. This means that there is the greatest possible variation in precipitation from locality to locality. For instance, one valley may be suffering from a prolonged drought while only a few miles away there may be a sufficiency of moisture. Therefore if it is found, for example, that the precipitation for Camuy was at a certain figure for any month, it does not

mean that the country directly to the south had the same amount of rain by any manner of means.

Considering the annual precipitation, it is found that Arecibo tends to approach the average for the Island, that Isabela and Camuy fall below, often as much as twenty inches, but that Utuado and the districts east of Arecibo exceed the average. A serious drouth in the region from Arecibo west occurred in the first months of 1916, and was preceded by excessive rainfall during the latter part of 1915. A similar drouth occurred during the first part of 1917 but was not so serious as that of the preceding year. This state of affairs was sufficient to bring on a serious condition of the cane. In fact it had a tendency by the yellowing of the leaves and stunting of stools to obscure the mottling. That it had no relation to the disease is evident when it is considered that Utuado and other districts which had not suffered from these severe drouths, at least as far as the weather records show (Utuado had 21.70 inches of rain from January to April, 1916), have also been severely infected, and that although the season of 1917 was normal as to precipitation the disease spread unchecked.

An experiment to test the effect of the moisture supply was set up in the plant house in the same manner as already described for other tests there, using black loam soil. Half of each of four series of ten cans was planted with normal cuttings, the balance with diseased. The resulting plants were allowed to grow several months, being watered normally or about once a day on the average, until they were about eighteen inches in height and well established. Beginning at this period one series of ten cans was watered to saturation, drainage holes in the bottoms being plugged; one series was watered normally; and two series were watered only at long intervals when wilting became pronounced. About one quart at ten day intervals was the amount given this series. At the end of two months one of these two latter series was treated as the first one, the soil being kept practically saturated for the duration of the experiment. The purpose of this was to simulate the alternation of drouth and long periods of rainfall, such as are of common occurrence in the western sections of the Island.

Normal cane made the better growth in all cases, which condition was particularly noticeable in the heights attained during the first few months. Canes under drouth conditions practically ceased to grow with the cutting off of the water supply and most of the series finally died. Much the same effects resulted in the saturated series. There were no other results.

A similar experiment was set up in three series of ten cans each using the red clay subsoil. These were treated in the same fashion as the preceding except that the alternation series was omitted. It was necessary to supply chemical fertilizer to secure satisfactory growth even in the normally watered series. Here again there was a dying of plants in dry and saturated soils of both normal and diseased lots.

The same series planted in a white sand gave the same results, it also being necessary to supply fertilizer to secure growth. Based on the results of the field survey and the plant house experiments it is a safe conclusion that water supply has no direct influence on the mottling disease.

NATURE OF THE DISEASE AND POSSIBLE CAUSES.

The endeavor to learn definitely the nature of this disease has proven rather baffling, and has led to experiments and studies along a considerable number of lines. Several theories have been tentatively considered from time to time, each of which has in turn given way to another as more facts came to hand. The progress of these studies will be briefly reviewed with the addition of such data as has been obtained since the writing of the last report.

It was first thought that the trouble was a manifestation of deterioration or running out of an old long established variety, the situation being accentuated by unfavorable climatic conditions. This view was soon abandoned because of the spread of the disease to other varieties and to districts where weather conditions had been normal. Much of this deterioration trouble is present, however, in all sections and represents a problem of no little importance, but is so sufficiently distinct that confusion need not arise.

Degeneration, a theory advanced at one time to account for the disease, likewise proves unsuitable in the light of further facts as the following exposition will make clear.

Inoculation tests.

Although all inoculation tests made in the preceding year gave negative results, field evidence proved rather conclusively that the disease had means of transmission other than by infected seed pieces, so that it seemed desirable to make further trials at artificial transfer of the disease.

In the first experiment a typical mottled stalk was ground in an ordinary food chopper and the expressed juice used as the inoculum. A hypodermic needle was employed to make inoculations.

Tallos Cancerosos. Variedad Cavangerie

(Caña de Vino)

Cankered Stalks. Variety Kavangerie.

A convenient plot of cane (Yellow Caledonia) some distance from any infection areas was selected and twenty-two stalks in all stages of growth from six inches in height to mature canes were inoculated. The punctures were made in some instances in the buds, in others at the growing point, and in still others into the internodes. Corresponding stalks were punctured as checks but not inoculated. None of these stalks, neither the inoculated nor the checks, has shown any signs of mottling.

As a second test another diseased stalk was similarly ground to furnish the inoculum and the material applied as before to canes of the variety B–3922 growing in the plant house. Twelve lots were inoculated in various ways with corresponding checks. Results were again negative.

Three series of these experiments were made the year before the varieties involved being Otaheite (*Blanca*), Yellow Caledonia, *Rayada*, D–117 and B–376 for a total of over one hundred inoculations. No positive results were obtained at the time, nor have any of the stools shown mottling in the present season.

Acting on a suggestion that the mottling might be similar to bean mosaic in its reactions, a series of tests was made in the plant house by inserting small bits of diseased tissue into various parts of normal canes. A set of inoculations was also made by rubbing growing tips of a number of healthy stalks after a diseased tip had been crushed in the fingers. It had been found by investigators that the bean mosaic could be transferred in this manner but not by using the expressed juice. There had been no developments from these tests at the last observation.

Chemical tests of the juice.

Limited tests of the juice of diseased canes were made in the division of chemistry of the station, from canes furnished by this division, with particular reference to the glucose ratio and a possible reduction in sugar content. It has not been apparent at any time that data of any great bearing on the problem was obtainable in this direction, but it was considered desirable to try out this possibility in common with all others.

The results of some of these analyses are given in the following table:

Table III.—Chemical Tests of the Juice of Diseased and Normal Canes.

Date 1917	Condition	Source	Variety	Corrected Brix	Sucrose	Purity
July 23	Normal	Cambalache	Rayada	12.23	6.47	52.9
July 23	Diseased	Cambalache	Rayada	12.43	6.83	54.9
September 29	Normal	Rio Piedras	B-376	11.51	6.43	57 60
September 29	Diseased	Rio Piedras	B-376	11.51	6.84	59.42
October 17	Normal	Rio Piedras	B-208	13.88	10.40	74.9
October 17	Diseased	Rio Piedras	B-208	12.68	8.75	69.0
November 8	Normal	Rio Piedras	B-3922	15.84	12.47	78.72
November 8	Diseased	Rio Piedras	B-3922	14.47	12.57	86.86
November 8	Normal	Rio Piedras	B-3922	14.88	11.89	79.90
November 8	Diseased	Rio Piedras	B-3922	14.98	12.20	81.44

It is realized that handmill tests of the juice of one or a few canes only cannot be taken as conclusive, but it is thought that these tests are sufficient for comparative purposes. It seems apparent that canes in the first stages of the disease, that is before the cankers and splitting are present, are but little affected, as far as their sugar content and purity of the juice are concerned. Losses would be due to a reduction in tonnage as indicated in the experiment by Lyon already described. In fact as will be noted from the table diseased canes in some cases actually showed a higher sucrose content than corresponding normal canes. Individual differences in age of cane or other factors explain this, however, since the two lots of cane always came from separate stools of course. It is interesting to note that at least one Central reported the same state of affairs in their mill tests in contrast to others which claimed a high glucose ration. As already noted this high glucose content is thought to be due to the fact that in advanced stages the openings in the rind splits and cankers) permit the entrance of bacteria and fungi with resulting fermentation.

As a final test along this line two lots of cane of the variety B–3922, one diseased and one normal were cut, care being taken to obtain canes as nearly of the same age, size, and other conditions as possible. Two canes of each of these lots were analysed by Mr. J. López Domínguez daily as long as the samples lasted. The results are given in the following table:

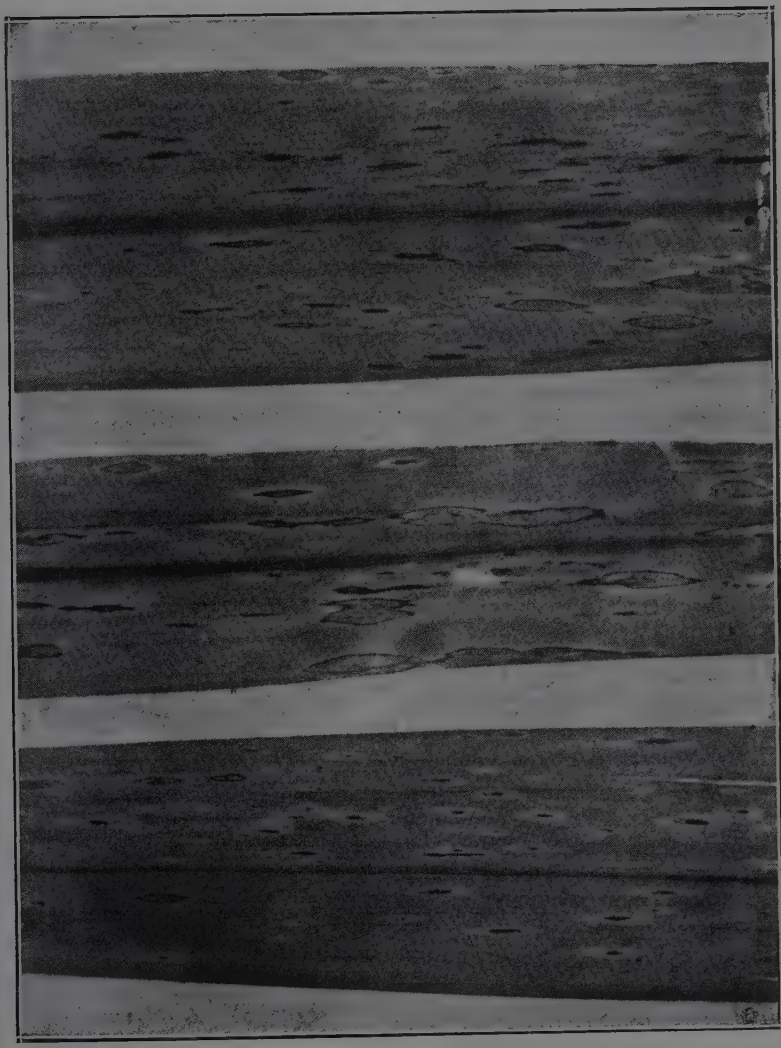

FIG. 6.—Leaf spot of cane. (*Helminthosporium sacchari.*)

Table IV.—Chemical Tests of Diseased and Normal Canes.

Date 17	Condition	Brix	Sucrose	Purity
November 13	Normal	14.90	11.96	82.96
November 13	Diseased	15.10	12.00	79.47
November 14	Normal	13.80	10.55	76.44
November 14	Diseased	14.10	10.74	76.17
November 15	Normal	15.20	11.07	72.82
November 15	Diseased	14.20	10.24	72.11
November 16	Normal	13.00	5.42	42.07
November 16	Diseased	13.58	9.45	69.58
November 17	Normal	14.76	9.37	63.48
November 17	Diseased	14.00	8.40	60.00
November 19	Normal	14 93	10.20	68.31
November 19	Diseased	13.53	8.71	64.37
November 20	Normal	15.8	10.8	68.35
November 20	Diseased	15.2	10.06	66.18

Here again no constant differences appear, confirming the results of the previous tests.

Relation of fungi or bacteria.

Leaves.—From the appearance of affected leaves, the presence of fungi or bacteria as causative organisms would not ordinarily be suspected. Early in the work sufficient examinations were made to clear up any doubts as to this point. Microtome and free-hand sections failed to show any differences between normal and diseased leaves other than the absence or deficiency of chlorophyll in the chlorotic spots. A number of attempts were made to obtain by the plating out process a responsible organism but none appeared. Those forms obtained did not occur uniformly and were either plainly saprophytic or the characteristic symptoms produced by them on the leaves when parasitic were well known. They were found on the older leaves for the most part, recently unfolded leaves proving generally free of any organism.

Particular attention was given on field trips to the relation, if any, of the various leaf-spot diseases to mottling but it was never possible to find any such connection. There was practically as much spotting due to *Leptosphaeria sacchari* and *Helminthosporium sacchari* on normal as on mottled cane.

Stalks.—Sufficient work to amply justify the conclusion that organisms attacking the stalk were not directly involved as causes of the disease were carried out last year, and may be here briefly reviewed.

The absence of any distinctive internal symptoms in the form of rot or gumming made it very doubtful from the first whether a parasite would be present. A special search was, of course, made for rind disease (*Melanconium sacchari*), red rot (*Colletotrichum*),

gumming (*Bacterium vascularum*), or other parasitic stalk diseases. Suffice it to say that while isolated cases have been found of the common stalk diseases of Porto Rico (gumming does not occur here) they have not been present to even an extent where appreciable damage was being caused, nor was there any connection with the mottling.

The common, easily recognizable fungi having been eliminated, attention was turned in the laboratory and in the pot cultures to an attempt to find a more obscure parasite or other cause. Tissue cultures and damp chamber tests were made from time to time, both of cankered stalks and of stalks which were normal appearing except for leaf mottling. Cultures of representative cankers made November 1 gave *Valsa* sp. and *Trichoderma lignorum*. On November 11, tissue cultures of stalks of B–208 and Yellow Caledonia proved sterile. In sterile moist chambers sections of the stalks produced a growth of *Trichoderma*, and in one instance of *Schizophyllum*. Seven lots of cankered canes were tested in damp chambers under sterile conditions, beginning December 26. Of these, two remained sterile, one produced *Trichoderma*, and four were overgrown with *Aspergillus niger*, but were otherwise sterile.

Similar tests were made in January of portions of mottle-leafed and cankered stalks brought in for planting tests. Pieces of eight stalks of Otaheite, Rayada, B–3412, and Sarangola produced only the customary saprophytes mentioned above.

A further series of tissue cultures was made, all precautions to obtain sterile conditions being taken. Short sections of stalks were immersed in mercuric bichloride (500–1) for several minutes, rinsed in sterile distilled water, and in the culture chamber, fragments removed with sterile instruments for planting in beef agar plates. The majority remained sterile until completely dried out, *Aspergillus niger* appearing on some, but quite plainly as a contamination.

To still further examine into any possible relation of the more commonly occurring fungi, several inoculation experiments were carried out. In the first of these *Colletotrichum falcatum* was used as the inoculating agent, and D–117 cane as the host. Ten stalks were punctured with a hypodermic needle and material from a pure culture inserted. Ten other stalks were similarly prepared, except that sterile water was used in place of the fungus. From time to time inoculated stalks were cut and examined. At no time was there any evidence of even the beginning of red rot. The only abnormal sign was the red discoloration around the puncture, such as occurs around any wound. The checks remained without change.

In addition to these laboratory experiments several extensive field tests were carried out with *Colletotrichum falcatum* and other fungi commonly occurring on diseased cane. As mottling did not appear in any of the canes grown in these experimental plots it was evident that the fungi were saprophytic only, or at least had no connection with the mottling. These tests are reported in detail in the 1916–17 report.

Nature of the cankers.

The cankers or lesions on the stalks of badly diseased cane are apparently the result of the general weakening of the stalks. Since, as has already been mentioned, they are first noticed before the leaf-sheaths loosen, and hence before fungus spores or bacteria could have penetrated, they are not primarily due to the action of fungus parasites. This conclusion is borne out by the cultural studies made. The various fungi, which are always present in abundance in and about the cane stools, doubtless are washed down as spores or mycelial fragments behind the leaf-sheaths as soon as these latter become loosened. The lesions already formed are then enlarged in size and depth by their action. They cannot, however, be concerned to any extent as primary agents since otherwise innumerable cases of red rot, rind disease, and other stalk rots would be found, the fungi causing these being omnipresent in all cane fields. Inoculations in an attempt to produce cankers have failed.

Bud tests.

While taking notes on the experiment in the plot of B–3922 a considerable number of stalks were found from time to time which showed mottling on the upper leaves only. When a new stalk became diseased, or rather when it first gave external evidences of being diseased, the mottling symptoms first appeared in the unfolding leaves. All succeeding leaves would then be mottled but the lower leaves would continue green and unchanged. At the transitional region one or more leaves might be marked in part only, for instance for a few inches out from the base, for half the length, or on one side of the mid-rib only.

All such stalks encountered were tagged at the point of transition and after growth had progressed long enough to form a number of nodes above the tag, they were cut for planting tests. These were conducted in the plant house, and the aim was to ascertain as to whether or not the entire stalk contained the virus of the disease, or only the portion above the transitional area. The buds were numbered from the bottom up, the stalk cut into two-eyed

cuttings and the ends tarred. Ordinary soil was employed in which cane had not been previously grown.

Details of the behavior of buds from several characteristic stalks will suffice to show the course of the experiment.

Stalk No. 124.—Cankered above the point where mottled leaves occurred. Shoots from all eyes mottled.

Stalk No. 175.—Cankered and split above the transition. All buds produced mottled shoots.

Stalk No. 2.—No cankering, though the stalk was not normally plump between the nodes. All buds produced mottled shoots which remained so throughout the season.

Stalk No. 193.—Cankers and shrinkage of the stalk present over several internodes below the transition. All shoots produced were mottled.

There were no exceptions to this sort of behavior in any of the series of plantings made of stalks of this nature.

Effect of chemical applications.

One of the possibilities that immediately suggested itself when studies of the disease were undertaken was that it was due to lack of iron, or to inability of affected plants to assimilate sufficient iron in the presence of an excess of some other chemical.

Potted specimens were sprayed with a four per cent solution of ferric ammonium sulphate, iron potassium sulphide, and ferrous sulphate, the only iron compounds at hand at the time. There were absolutely no results from this treatment.

In a latter experiment ferrous sulphate alone was used. Of ten plants, two were left as checks untreated, four were sprayed with a ten per cent solution and four with a five per cent solution. Several grams of the crystalline salt were placed in the soil of each pot. This treatment was repeated three times at intervals of a week. There having been no observable results after a lapse of a month, 125 cubic centimeters of ten per cent solution was poured on the soil of the first four, and the same quantity of five per cent solution on the other four. Again there were no results and the cane was cut to permit it to ratoon. After another month the solutions were again applied as above to the new shoots, but without results. It was apparent that the disease was not related to the chlorosis diseases of pineapple or cane, which have been clearly shown to be due to lack of iron in the soil, or to inability of affected plants in the presence of an excess of iron to assimilate sufficient iron for normal growth.

Copper sulphate was also tried with the view in mind that it might serve to restore normal green color to mottled leaves. Two plants were sponged with a two per cent solution, two with a five per cent. A quantity of each strength was also poured on the soil of each pot. This was repeated twice over a period of two months, but without the slightest effect. Mottled shoots remained mottled at all times.

Manner of transmission of the disease.

A number of tests were made to ascertain as to whether or not the disease was carried over in the seed. For this work five-gallon oil cans only were available, which were rather small for growing cane to maturity. In all of these plantings the seed pieces were recut prior to planting, soaked fifteen minutes in Bordeaux mixture and planted immediately. Unless otherwise noted, the soil has been a fair quality black loam such as is used in all propagation work at the station.

The first planting was made on December 9, seed for checks being taken from fields on the station grounds. Examinations were made from time to time as to the presence or absence of mottling, and the number of shoots produced. Neither in this experiment nor in any of the others was there any apparent correlation between the disease and the number of shoots produced. The results of the first and last examinations only are given unless intervening dates showed facts of importance.

Table V.—Results of First Series of Pot Experiments.

Group	Can No.	Soil	February 8, 1917	July 25, 1917
A	1	Sterilized (steam)	Leaves mottled	Leaves mottled
	2	Untreated	Leaves mottled	Leaves mottled
	3	Untreated	Leaves mottled	Leaves mottled
	4	Untreated	Leaves mottled	Leaves mottled
	5	Untreated	Leaves mottled	Leaves mottled
B	6	Sterilized	Leaves mottled	Leaves mottled
	7	Untreated	Leaves mottled	Leaves mottled
	8	Untreated	Leaves mottled	Leaves mottled
	9	Sterilized	Leaves mottled	Dead
C	10	Untreated	Leaves mottled	Leaves mottled
	11	Untreated	Dead	
	12	Untreated	Leaves mottled	Leaves mottled
D	13	Untreated	Leaves mottled	Leaves mottled
	14	Untreated	Leaves mottled	Dead
	15	Sterilized	Leaves mottled	Leaves mottled
	16	Sterilized	Leaves not mottled	Leaves doubtful
E	17	Untreated	Leaves not mottled	Leaves not mottled
	18	Untreated	Leaves not mottled	Leaves not mottled
	19	Sterilized	Leaves not mottled	Leaves not mottled
F	20	Untreated	Leaves not mottled	Leaves mottled
	21	Untreated	Leaves not mottled	Leaves not mottled

A. *Yellow Caledonia.*—Seed obtained from near Arecibo, plant

cane, seed for which was obtained from this station. It had been planted in soil said never before to have been in cane, although surrounded by diseased fields. The field showed about thirty per cent of mottling, and later the first ratoons were a total failure. This test was made with uncankered stalks, the leaves of which were mottled.

B. *Rayada.*—From near Arecibo, typically mottled and cankered, nodes shrunken.

C. *Yellow Caledonia.*—Same as A, except that the stalks were lightly cankered, and but little shrunken.

D. *Same.*—Stalks very badly cankered and shrunken.

E. *Check. D–117.*—Seed from station fields.

F. *Check. Yellow Caledonia.*—From station fields.

Soil for the second experiment (planted December 13, 1916) was a heavy clay obtained from a field in the Arecibo district, which had been abandoned to cane culture because of the disease. A portion of this was sterilized (cans Nos. 1, 2, 3) by steam (one hour at about sixty pounds pressure), and the remainder untreated. The seed used was the same as that of the first planting.

Table VI.—Results of Second Series of Pot Experiments.

Can No.	Seed	February 8, 1917	July 25, 1917
1[1]	B	Leaves mottled	Leaves mottled
2[1]	D	Leaves mottled	Leaves mottled
3[1]	E. F	Normal	Leaves mottled [2]
4	B	Leaves mottled	Leaves mottled
5	A	Leaves mottled	Leaves mottled
6	A	Normal	Normal
6a	F	Normal	Leaves mottled
7	F	Normal	Normal
8	D	Leaves mottled	Leaves mottled
9	C	Leaves mottled	Leaves mottled
10	E	Normal	Normal

[1] Soil sterilized.
[2] Mottling was first noted on two out of six shoots on March 6, this proportion continuing until June 25, by which time all were affected.

On December 23, another set of plantings was made in order to obtain further data on canes which were being examined in the laboratory at the time. Steam sterilized soil was used.

1. *Caña de vino* (*Cavengerie*).—A stalk from Camuy, apparently normal but from a stool other stalks of which were showing mottling. In the local test all shoots from buds of this stalk remained normal.

2. *B–3412.*—Stalk of mottled cane obtained near Camuy, seed for which had been sent from this station. Most of the field was showing mottling. All shoots from the piece planted were mottled.

3. *Otaheite.*—From near Camuy, a field showing 100 per cent infection. All shoots produced mottled.

4. *Crystallina.*—A diseased stalk from near Camuy, field showing about fifty per cent of disease. All shoots mottled.

A fourth and final planting experiment was started January 5, using the ordinary station potting soil untreated. The seed was all obtained from various badly diseased fields near Central Alianza.

Table VII.—Results of Fourth Series of Pot Experiments.

Can No.	Variety	Condition of seed	February 8, 1917	July 25, 1917
1	Caña de vino	Normal	Normal	Mottled [1]
1 a	Caña de vino	Diseased	Mottled	Mottled
2	Bamboo	Cankered	Mottled	Mottled
2 a	Bamboo	Diseased	Mottled	Mottled
3	Caña de vino	Normal	Normal	Normal
3 a	Otaheite	Normal	Normal	Normal
4	Bamboo	Cankered, mottled	Mottled	Mottled
4 a	Bamboo (same stool)	Normal	Normal	Mottled
5	Caña de vino	Normal	Mottled	Mottled
6	Caña de vino (same stool)	Mottled	Normal (?)	Doubtful
6 a	Caña de vino (same stool)	Cankered, mottled	Mottled	Mottled
7	Yellow Caledonia	Normal	Normal	Normal
7 a	Yellow Caledonia (same stool)	Cankered, mottled	Mottled	Mottled
8	Rayada	Normal	Mottled	Mottled
8 a	Rayada (same stool)	Mottled	Mottled	Mottled

[1] Changed to diseased condition during May.

These results seem to warrant certain conclusions as to the behavior of diseased canes, although it is recognized that they are by no means conclusive. However, even from the limited tests made it is quite certain that all cane shoots springing from seed pieces which were from cankered or mottled-leaf stalks will be diseased in spite of soil sterilization and disinfection of the seed. One exception only occurred in our tests, and that one was very doubtfully normal.

Of the various seed pieces taken from apparently normal stalks or stools which were diseased in part, about half produced normal shoots and the remainder mottled. This phase of the experiments is rendered uncertain by the fact that a stool of cane under the planting system usually employed in the western portion of the Island consists of the growth from about four seed pieces, and since it is apparent that the disease is transmitted through the individual seed pieces, it is undoubtedly a fact that many instances of planting of one or two diseased seed pieces together with normal ones accounts for the presence of both types of stalks in the same stool. After the first cutting it is difficult to trace the separate plants composing the stool. There have been found, however, examples of normal and mottled shoots arising from the same rhizome. The virus of

the disease is present in all such stalks whether they show outward signs or not, and this fact will account for the results obtained in the above described planting tests with apparently normal stalks from mottled stools.

The above experiments were those conducted in the previous season but the results have been confirmed most conclusively by all work since that time. All plantings, without exception, of cane from mottled stools made in the plant house and field experiments to a total of several hundred produced typically mottled shoots.

The following results from an experiment by Mr. Bourne of Guánica Central add further exact data.

"In January 1918, 100 cuttings taken from diseased stalks of B–3922 were planted in Tablón No. 8 at Santa Rita alongside of 100 cuttings taken from absolutely healthy stalks of the same variety. Both kinds of cuttings gave practically the same germination. Early in March an examination was made and it was found that all the shoots from the diseased cuttings had the mottling disease while those from the healthy cuttings had no sign of the disease. The diseased cuttings were then dug up and destroyed and the space replanted with healthy cuttings which have all germinated. At the time of writing an examination was made of the shoots from the healthy cuttings and about 1.7 per cent of them have developed the disease. From this experiment the importance of carefully selecting cuttings is very evident. It also proves that although a field is planted with healthy cuttings, the cane develops the disease after germination."

It was very important to know before any system of control could be evolved whether the disease remained in the soil or not so that infection of healthy plants could occur from that source. To ascertain this under controlled conditions a series of ten mottled plants were selected in the plant house, the canes cut off at the surface of the soil and the underground portions cut sufficiently to prevent any ratoon growth. Seed pieces of normal B–3922 were then planted in each container. The stool from which the seed was obtained was marked as a check. No mottling appeared on any of the resulting plants throughout the season, nor on the following ratoons. The second series of pot experiments reported gives a further verification of this result.

A series of forty pots was prepared in the same manner, using mottled plants that had been used in other experiments, and replanting with normal B–3922 as before. This test is still under observation but there has been no infection as yet of the new shoots.

Similar experiments have been carried out in other sections of the Island on a field scale with comparable results. Some infection occurs of course in such cases but is explainable by aerial transmission of the disease.

It seems certain that the disease does not persist in the soil and that hence infection does not occur through the roots or rhizomes. It may, however, pass from the underground parts of a diseased plant to a healthy one where the two are in contact, although no certain evidence has been obtained on this point.

It is thus absolutely certain that the mottling disease is transmitted by means of diseased cuttings and this fact serves to explain in considerable part the spread of the disease from field to field, its appearance in fields never before planted to cane, and similar questions. Not only has there been no attempt on the part of many growers to avoid use of such seed until the disease was present in overwhelming amount, but it has too often been true that such material has been planted in preference to healthy seed, since it was possible to sell the latter for grinding while the former was refused.

The use of diseased seed will, however, explain the spread of the disease in part only, and it has become very evident as a result of field observations that there is some other method of transmission. In the absence of fungi or bacteria as causative agents whose transmission could be accounted for by wind, water, and other natural agencies it is rather difficult to arrive at any satisfactory conclusion.

In the absence of any exact information the theory of insect transmission will be but mentioned and left for other workers to investigate and report upon. The writer feels certain that insects will be found which are capable of carrying the disease and this will then explain the appearance of the mottling in isolated valleys as well as accounting for its rapid advance from west to east. Wind cannot be considered as a carrier since the advance of the disease has been against the direction of the prevailing trade winds. It is supposed as another part of this hypothesis that these insects or insect occur primarily in the uplands, due to the presence there of wild host grasses, thus accounting for the prevalence of the disease in upland districts, and its rather peculiar behavior in jumping from valley to valley rather than working along the continuous coastal areas. The insects suspected in this connection are small sucking forms known as leaf-hoppers. Further support of this hypothesis is given in the discussion of the similar disease of sugar beets known as "curly-top," where the causal relation of a leaf-hopper has been definitely proven. Aphids (*Sipha flava* and *S. graminis*), and the

mealy bug (*Pseudococcus sacchari*) have been also suggested, but it does not seem possible that these species which are so commonly present can be involved. They were present in abundance in the plant house in spite of precautions to prevent their entry, but there was no transferance of the disease, even though ants which carry them from plant to plant were also very abundant.

Conclusion.

With the mass of evidence presented it seems safe to conclude that the mottling disease of cane is an infectious chlorosis allied to similar diseases of cane, and other crop plants to be mentioned in following pages. It appears that it is not influenced by cultural factors, that fungi or bacteria are not present as causal agents, and that faulty assimilation or nutrition are not responsible.

There is an infectious principle present in all parts of infected plants whether evident externally or not, which is transmitted in cuttings, and has some other mode of aerial transmission not yet ascertained. The causal agent may be considered an ultramicroscopic organism as is known for some animal diseases and has been held responsible in the case of the tobacco mosaic. For those who do not believe in the possibility of such organism there is of course the theory of deranged enzymes. These will be found present of course in either event since enzymes not ordinarily present in healthy cane, or abnormal amounts of those that are always present, would result from the attacks of the ultramicoscopic organisms.

The weak point in this theory lies in the fact that it has not been possible to artificially transmit the disease to healthy plants, although there has been abundant field evidence that such transfers do occur in enormous numbers. This is held to be a problem that will be finally solved by changes in technique or manipulation of the virus. Similar difficulties have been had with other diseases attributed to similar causes.

COMPARISON WITH DISEASES OF A SIMILAR NATURE.

Yellow striping.

A very interesting situation has arisen over the possible identity of mottling and a disease of Java and Hawaii known to the Dutch workers as "Gele Strepenziekte" or yellow striping as the name has been translated and applied in Hawaii. Lyon[1] of the Hawaiian Sugar Planter's Station in commenting on the writer's paper (32) published in phytopathology first directed attention to this possi-

[1] Unpublished note.

bility. In fact he went further insisting that they were identical and insinuating that the mottling was neither "new to Porto Rico" nor "alarming" as stated in the article in question. In passing it may be pointed out that the figures already given will testify to the alarming nature of the disease and it is quite certainly new to the Island. No claim was made as to its being new to any other part of the world.

The "Gele Strepenziekte" was first mentioned by van Musschenbrock (37) in 1892 and in the following year Wakker (38) published on the same disease. Since that time there have been a number of other articles dealing with it in the Javan sugar-cane literature, which will be found listed in the bibliography appended. Both Wakker and Went (39), and Krüger (18) deal briefly with it. It is said to have been first noted in Hawaii in 1909. The report of its occurrence there as well as a number of articles published since, dealing with the nature and prevalence of the disease have appeared in the Hawaiian Sugar Planter's Record, which publication has not of course been available for reference.

Concerning this yellow stripe disease Lyon writes as follows.

"It is an infectious chlorosis akin to the mosaic disease of tobacco, The causal agent operates at the growing point of the stem and in the unexpanded leaves which are rolled up in the spindle. Every lateral bud is infected as it is formed, so the disease is certain to be transmitted through cuttings from infected stalks. All varieties of cane growing in Hawaii are susceptible to this disease, but some much more than others. Likewise some varieties are far more sensitive to the disease than others, while others stand up well under the disease.

"In Java and Hawaii the disease is held under practical control by the selection of healthy sticks only for cuttings.

"We have authentic records of the occurrence of yellow stripe disease in Hawaii, Fiji, Australia, New Guinea, Java, the Philippines, and Egypt."

With the exception of the brief paragraph in Krüger's work, none of the Javan references were seen until after the writer's connection with the mottling work had been ended. Since then several of the more important ones have been obtained. In particular the plates in the article by Wilbrink and Ledeboer (40) were examined, and while these illustrate a phenomenon which resembles mottling, considerable doubt is still entertained as to the identity of the Porto Rican and Javan diseases. As far as the writer is concerned it has

not been thought advisable to jump to the conclusion that the two diseases are identical since specimens of the yellow striping have not been available for comparison.

Lyon as noted has been positive of this identity basing his opinion on an earlier paper (32) of the writer. Since then it is reported that he has examined authentic Porto Rican material and confirmed his preventious diagnosis.

Sereh.

A very baffling disease of cane known as sereh has been present for many years in Java having been epidemic at one time. It has also been reported from other eastern cane-growing countries. It resembles mottling in some respects so that a short comparison of the two as to signs and characteristics will not be out of place. Dr. Smith's (25) account of the Sereh is followed in the main.

"The sereh appears at first only sporadically; the year following one finds usually sereh plants everywhere and the third year the disease occurs in such severity (when no measures are taken againt it) that a failure of the crop results." This corresponds very well to the course of the mottling disease. Other signs are also in close agreement, principal of which are the transmission of the disease from old plants to new ones by means of cuttings and a shortening of the internodes. On the other hand sereh is described with a number of points not noted in connection with mottling important of which are the presence of gum, slime, or crystals in the bundles or parenchyma tissues of the stalk, red staining of the bundles, yellow stripes (not mottling) of the leaves, excessive production of new shoots and roots above ground, the clinging of the leaves beyond the usual time of falling, and the dying of the foliage from below upward so that apparently the top of the cane is less diseased. Certain other points, particularly the inclination to bloom early, have not been noted sufficiently well to be contrasted. In addition the Porto Rican disease possesses the very characteristic mottling and cankering of the stalks lacking in sereh.

Every possible cause has been asigned by one worker or another to sereh, including plant and animal parasites to a considerable number, unfavorable soil conditions, wrong fertilizers, abnormal weather (drouth or excess of water), degeneration, dying of the roots, and improper cultivation practices. Workers on the disease have not settled on any definite cause as yet.

Without, of course, ever having had any experience or direct knowledge of sereh, the writer is very much inclined to believe that

the mottling is a disease of the same nature and that both are due to ultramicroscopic organisms.

Curley-top of sugar beets.

A study of the literature on the "curly-top" of sugar beets has shown many points of agreement with mottling, and the desease is of especial interest because of the relation of a certain insect as the carrier of the infecting agent.

This is a disease which causes a distortion of sugar beet leaves, and a dwarfing of the plants with an accompanying reduction in yield. The losses vary from season to season but have often reached $1,000,000 in the western United States. Various theories have advanced from time to time but it was finally proven by Ball (4) that a leafhopper (*Eutettix tenella*) was responsible for transmission of the disease, and this conclusion has been verified by other workers. The insect in question is a native species found on a number of indigenous plants. Under certain conditions these insects pass in swarms to the sugar-beet fields, the curly-top developing soon after.

It was found that leafhoppers "taken from wild plants did not transmit the disease until they fed on diseased hosts. Three hours on a beet rendered them pathogenic. It is probable that some wild plant carries the disease and leafhoppers coming from this plant are able to transmit it to the beets" (Ball).

A most interesting feature of the work on this disease as it relates to the sugar-cane situation is the fact that it has never been possible to transfer the disease by inoculations, although it has been transferred by grafting. Mottling could of course also be transferred in this manner if grafting of monocotyledons was possible.

Tobacco mosaic.

Probably the best known of the diseases of this class is the tobacco mosaic (2, 6), which occurs in practically every tobacco growing country in the world including Porto Rico. Affected leaves are mottled or blotched and in other than light cases distorted. Diseased plants are greatly stunted. Although the disease is highly infectious it has never been possible to find fungi or bacteria present as causal agents. It is very easy to transmit the disease to unaffected plants by rubbing them lightly with the fingers after crushing a diseased leaf. In fact a great number of plants can be infected by an exceedingly small quantity of the virus, and it is by handling that the infection is spread to a large extent.

Two theories are held as to the cause, one considers ultramicroscopic organisms as the causal agent, the other enzymes or the

product of enzyme activities. The former seems the preferable theory. Insects, particularly one or more species of aphids have been demonstrated to be capable of carrying the virus. The striking point of difference between tobacco mosaic and cane mottling is the failure to date to carry out artificial transmission of the latter, which is so easily done with the former.

Spinach blight.

Spinach blight (21) is a disease of the trucking region of the eastern United States, and has caused annual losses as high as $200,000. It is a specific disease characterized by a mottling and transformation of the leaves, and a decided stunting of the growth. Diseased plants may occur in definite areas or they may be scattered over the field.

Fungi or bacteria have never been found associated as causal agents. Nature of the soil, fertilizers, drainage, and other cultural factors, though all considered at different times have been found to be without any direct relation to the disease.

It has been possible to transmit the blight by transfers of the juice of infected plants. Certain species of aphids and one in particular (*Macrosiphum solanifolii*), have been demonstrated to be carriers of the virus and very interesting data has been collected on the relation of these insects to the disease. The causal agent is considered to be an ultramicroscopic organism.

Peach yellows.

Peach yellows has been known in the United States for considerably over a hundred years and has caused very heavy losses. It is characterized by a premature ripening of the fruit which is red spotted as well as being of poor quality. Slender abnormal appearing shoots are produced from the trunk, which bear pale yellowish-green leaves. Leaves on the normal branches may also be yellowish-green.

No remedy has ever been found and infected trees invariably die after a number of years. Pruning of infected branches is always without avail, the virus being present in all parts of infected trees, even though portions appear normal. Control is secured by dugging out diseased trees as fast as they are discovered.

The usual range of supposed causes including poor culture, wet or dry weather, wrong fertilization, insects, fungi, and over bearing has been gone over by various workers and all finally shown to be of indirect importance only. Here again the cause is doubtless an ultramicroscopic organism, although the enzyme theory has also been advanced. No insects have as yet been found which act as carriers.

It has been found possible to infect healthy trees by budding or grafting in diseased material.

Cucumber mosaic.

A disease, which has but recently made its appearance in the middle west where it is said to be the most serious disease of the crop present, is the cucumber mosaic. Typical mosaic symptoms are produced with a pronounced dwarfing or even final death of infected plants.

It has been found possible to transmit the disease artificially by inoculations, and the striped cucumber beetle has also been proven a carrier of the infective principle. The disease has not been found to carry over in the soil or to be carried in the seed. A number of other species of the *Cucurbitaceae* have been found susceptible upon inoculation, but the same is not true with beans, tomatoes, potatoes, tobacco, or other non-cucurbitaceous plants. Those who have worked on the disease consider the cause to be still in doubt, but from the facts known concerning it seems to fall readily into the class of diseases under consideration.

Potato mosaic and related abnormalities.

Under this heading may be grouped for discussion those diseases or abnormalities of potatoes variously known as mosaic, curly dwarf, and leaf curl. By some workers they have been considered as merely varying phases of one disease and by others as distinct. They are sufficiently alike to indicate the same or closely similar causes.

Leaf roll is characterized by an upward rolling of the leaflets at the tips of the branches or even of the entire plant in severe cases. The normal green color becomes yellowish often with a red tinge. Affected plants are stunted. In the curly dwarf condition stems and leaves are shorter than normal, resulting in a dwarfing of the plants. The leaves are normal in color, but wrinkled and curled downward. The leaves of mosaic plants are, as the term implies, mottled and often wrinkled, resembling the same condition in tobacco leaves. All three of these abnormalities are transmitted through the tubers.

Most of the investigators who have considered these potato disease have decided that they were non-parasitic, and have favored the degeneration theory as an explanation. Prof. Stewart has summed up his observations as follows:

"A striking feature of the study was the frequency with which the progeny of plants having normal foliage and high yield suddenly degenerated into worthless dwarfs."

"There is no evidence that any one of the forms of degeneration named is communicable from one plant to another except through the medium of the seed tubers. They are not due to any parasitic organism, neither are unfavorable soil or weather conditions of the current season responsible.

"Neither normal foliage nor high yield is a guaranty of productivity in the progeny of the following season. Degeneration may occur quite suddenly.

"It is unsafe to select seed potatoes from fields containing many degenerate plants. Even the normal plants from such fields are liable to produce worthless progeny."

In the report of last year the writer applied the above conclusions to the mottling disease and so asigned it to degeneration. The further evidence obtained since that time very effectively combats this tentative theory and likewise leads to doubt as to validity of degeneration as a cause for the potato troubles. They would seem to belong more nearly in the infectious chlorosis group of diseases. Such a theory better explains the various phenomena reported, such as the sudden appearance of disease or "degeneration" and its manner of spreading.

A disease of beans also known as mosaic has been reported which clearly belongs to this group of diseases due to ultramicroscopic organisms or infectious virus. There are doubtless others as yet unstudied.

ABNORMALITIES WHICH MIGHT BE CONFUSED.

There are a number of abnormalities of cane due for the most part to non-parasitic causes which occur wide spread in Porto Rico and which can be and often are confused with mottling.

Deterioration.

This term is applied to the general unsatisfactory condition of cane so common in Porto Rico and apparently in all other parts of the world as well judging from the literature, which varies from a mere lack of vigor to a "running out." It is readily attributable to long continued cultivation of one variety, to unfavorable weather, to poor cultivation, and any other factor which tends to reduce the vigor of the plants. Harrison (13), who has given the most extended account of this matter, presents five principle causes for the deterioration or running out of cane varieties, basing his conclusions on observations of the downfall of the Bourbon variety in the West Indies. These causes are as follows:

"(1) Lack of vigor induced by continuous cultivation in the same soil.

"(2) Continuous cultivation of the land to the same depth.

"(3) No care being taken in the selection of suitable material for planting purposes.

"(4) Spread of diseases.

"(5) Changes in the varieties themselves."

The first three of these are primarily responsible for deterioration, at least under Porto Rican conditions; the fourth has, as far as the present situation is concerned, been eliminated; and the fifth is an indefinite statement but one which applies very well and helps to explain such points as why certain varieties after thriving for a time begin to fail.

The first symptoms as noted in the leaves may readily be confused with those of mottling. In fact, the spots or discolored areas can with certainity be distinguished only by their color, which is of a decided yellow rather than the white or nearwhite of the mottling disease. They are not to be differentiated from the yellow spotting described on a following page.

When the unfavorable circumstances persist, the deterioration becomes more marked, resulting in a dwarfing of the stools, dying of the leavesand roots, and general appearance of unthriftiness. It becomes especially marked in each succesive ratoon crop, and if the field be not abandoned an exceedingly large number of stools die each season. In these advanced stages the rhizome and base of the plant will be thoroughly rotted and permeated by the white mycelium of one or more fungi (*Himantia stellifera* occurs most commonly). It is this situation that has lead to the designation of this condition as "root disease" by many writers.

Deterioration is wide spread in Porto Rico, being especially common in its early stage for instance, where unsuitable varieties are being grown, where cultivation and fertilization have been delayed in heavy soils, or during periods of drouth. The fact that there is a recovery (that is the new leaves are normal) from this stage and that the growers have confused it with mottling, probably explains certain persistant claims that the latter disease has been "cured" by fertilization or other methods.

The former has always been a prominent factor in cane cultivation in the western portion of the Island because of drouth and cultural conditions prevailing there, and is still, of course, very much in evidence and still causing heavy loss. Innumerable cases

occur where it acts in connection with mottling, but sufficient observations and tests have been made to indicate that it is distinct from the latter malady.

The presence of a non-parasitic type of root disease resulting in deterioration has been recognized by other workers, particularly in Java. Wakker reports an hereditary constitutional disease characterized by yellow spots in the leaves, and Kamarling and Suringer (16, 17) studied a root disease due to a compacting of a heavy soil.

Root disease.

In addition to the above, there is another and somewhat similar disease quite clearly, however, parasitic in its nature. Several fungi occur in and about cane stools suffering from this type of disease. *Marasmius sacchari* has been the one most commonly held responsible but the writer does not believe that it is at all concerned. The stellate crystal fungus (*Himantia stellifera*) and the granular leaf-sheath fungus (*Odontia saccharicola*), the latter probably the perfect stage of the former, are of even more common occurrence. As already noted elsewhere (15) the entire matter of the relationships of these various fungi, and their connection with root disease of cane, is a subject requiring definite experiments under controlled conditions before exact statement can be made.

In typical cases of root disease there is no spotting of the leaves, other than that they are very susceptible to *Leptosphaeria*. They die back uniformly from the tips and along the margins, the lower ones dying first. For some time, except for the dead and dying roots and leaves, no other symptoms appear. Finally, however, one or other of the fungi mentioned grows up around the stalk binding the leaf-sheaths rather firmly together with a white mycelial mat. A musty odor is present. Practically none of this disease has been encountered in the territory where the mottling prevails.

Chlorosis.

Prominent among the abnormalities which have been confused with mottling is the whitening or yellowing of the cane leaves known as chlorosis which occurs only in a limited area on the south coast. This trouble is found generally in small definite areas from a few feet to an acre or so in extent. All canes in the given area will be affected so that the spots stand out prominently from the surrounding cane. Individual stools may be considerably stunted, and the leaves yellow to white in color. The discoloration in this case is uniform with no trace of a mottled appearance.

The cause has been definitely shown by Gile (12) to be due to

inability of the cane plant to assimilate sufficient iron due to the presence of an excess of lime in the soil. This trouble can be overcome to some extent by applications of manure and ferrous sulphate applied as a spray.

Yellow spotting.

Another very common abnormality of cane leaves and one which is wide spread in all parts of the Island is what has been designated as yellow spotting. Certain varieties notably Yellow Caledonia and B–1809 are very susceptible to it. It is characterized by small yellow spots with indefinite margins very much resembling the markings of mottling except that the latter are more nearly white, and generally more linear. A further point of difference lies in the fact that this yellow spotting attacks the lower leaves first, new leaves issuing from the bud being always of normal color. Yellow spoted leaves are very subject to *Leptosphaeria,* and other leaf spots, and very often fall prematurely.

This condition in the early stages yields to an increase in the moisture supply, and especially to fertilization and improved cultivation. It is not transmissible through the seed, except in so far as a general tendency to the trouble is concerned when conditions are not of the best. This phenomenon is to be considered as the first stage of deterioration.

White-striping.

There is a striping of cane leaves, already referred to as a chimera, which is common particularly on certain varieties. This consists of stripes of varying width, rarely including the better part of an entire leaf, and running the length of the blade. These stripes are of non-parasitic origen, and result from little understood reactions of a cell or group of cells at the growing point of the stalk. The same phenomenon is common on Indian corn (*Zea mays*).

Mite injury.

At one point of the work with the cane in the plant-house a phenomenon appeared on many of the plants which was practically identical with mottling. This was due to an undetermined mite very similar to the common red spider which is so common as a green house pest. In several instances the only way in which it was possible to make certain which was which was to unroll the young still-folded leaves at the center of the plant. If a mottled condition did not appear on these, the markings were mite work. These pests were finally checked through the workings of natural agencies.

FIG. 7.—Cane-sugar stalks, showing effect of sun burn.

Gray blotch.

This phenomenon consists of gray, very irregular patches (Pl. IV) on the internodes which often coalesce to encircle and practically cover the entire surface. They do not pass from one internode to another. These areas are superficial, including only the outermost layers of cells or practically the epiderm only. Certain varieties, notably B–347, are very susceptible to these markings. It appears probable that they are merely a result of sunburn, since they have been observed on stalks at the edges of fields or in positions exposed to the direct light. Fungi and bacteria may be helpers or secondary agents.

COMPARISON WITH OTHER CANE EPIDEMICS.

As a matter of general interest it is proposed to give a brief account of certain other cane disease epidemics of the past which will to some extent at least throw light on the present situation.

The Porto Rican Epidemic of 1872–80.

There have been several other serious epidemics of cane disease in Porto Rico before the present one. The one entailing the greatest loss (estimated at $796,500) occurred between the years 1872–80, reaching its height about 1876. A commission of three local men was appointed by the Government to study the disease and in 1878 they presented a lengthy report (1). The region infected as given in this publication, included the cane lands around Mayagüez, Aguadilla, Hormigueros, San Germán, Cabo Rojo, and to a limited extent some territory beyond these municipalities, both on the north and south coasts. This was what constituted the fourth department of the Island.

In many respects the observations of the commission corresponded with those noted for the present trouble. The disease spread rapidly, quite irregularly, and was not checked by rivers or hills. The symptoms are described as follows:

"Los fenómenos que presagian el principio de la enfermedad son regularmente cierto tinte amarillento que se nota sobre los cañaverales, el desarrollo tardío y difícil de las cañas, y una vez cosechadas y molidas, la baja en el rendimiento. Al año siguiente, en las cañas que nacen, al parecer buenas y lozanas, reaparece el tinte amarillento del primer período y continúan así hasta 4 ó 5 meses, que corresponden al desarrollo de los primeros cañutos.

"Después continúa el color verde amarillento en todas las hojas que acaban por secarse, primero las inferiores y sucesivamente las

demás, mientras los cañutos que van saliendo permanecen cortos y delgados; la yema terminal o cogollo se seca a su vez, y por fin, arrugándose primero los cañutos superiores o más débiles y después toda la caña, termina ésta por secarse completamente.

"Cañas enfermas procedentes de cañaverales enfermos, sembradas en terrenos sanos y distantes del foco de la enfermedad han producido cañas sanas, y cañas sanas extraídas de las más excelentes cañaverales, transplantadas a los que sufren o sufrieron han producido cañas enfermas."

There were no other consistent symptoms. The occasional cases of internal red rot and rot of the buds were probably due to specific causes. The common cane insects were studied and a decision made that they were not directly concerned. A study was also made of weather conditions with particular reference to drouth, but it was found impossible to make any correlations. All measures such as increased fertilization, use of lime, ashes, and a number of chemical poisons were without effect. The commission after frankly admitting that they had been unable to find a cause advised the immediate extension of planting of several hardy varieties, particularly Morada and Crystallina in place of the universally grown white cane (Otaheite), which had shown no resistance. They also advocated the introduction to the Island of new varieties from other parts of the world.

While in some respects this epidemic resembled the one now raging the perusal of the symptoms as compared with those of the latter does not make it seem probable that they are the same. No reference is made to mottling or stem cankers, but to a yellowing of the leaves only, followed by a drying of the bud.

Some years later Don Manuel Fernández Umpierre (11), administrator of Central San Vicente, published in his work on sugar-cane an account of the same epidemic and his experiences in controlling it. According to his statements, the disease yielded to careful cultivation with particular attention to drainage, even though the very susceptible Otaheite was used. It is quite probable that by the time he took up the problem the disease had about run its course, and even at its height it had hardly extended as far east as San Vicente. Other points, such as origin of the seed used in his experiments, are not sufficiently clear to warrant further discussion of this paper.

In 1895, Don Fernando López Tuero, director of an experiment station (not the present station) published (19) as part of his work on sugar-cane a lengthy article on what he considered to be the same disease. After investigation of a number of possible factors

he decided that white grubs (*Phyllophaga* spp.) are responsible, and proves this theory to his own satisfaction by a series of field observations and planting tests. The present writer inclines to the belief, after a close perusal of López's paper that he was correct in his surmise that white grubs were responsible for the death of cane over large areas. His description at least does not suggest the mottling disease, but is fairly exact for white grub injury.

Other Porto Rican cane disease epidemics.

This, so far as known, includes all recorded cane disease epidemics of any importance up to 1907. About this year trouble was again experienced with the Otaheite variety, this time in the Naguabo district. The disease here was very clearly a deterioration of a long planted variety brought about by rind (*Melanconium sacchari*) and root disease (*Marasmius, Odontia*), and other unfavorable conditions. The symptoms were characteristic in all respects for these two maladies, and no signs of mottling were seen at any time. The situation was overcome by the introduction of new varieties to replace the white (Otaheite).

It thus appears that although Porto Rico has suffered from severe epidemics of cane disease in the past, the present peculiar type has not occurred heretofore. Not only has the literature failed to bring out anything suggestive of it, but conversations with old residents who had personal knowledge of the sick cane of 1872–78 does not make it all probable that the two were the same, at least in so far as visual symptoms are concerned.

Serious cane disease in other cane regions.

Practically every sugar-cane growing country in the world has suffered at one time or another heavy loss from disease, deterioration, or a combination of the two. For example, Porto Rico 1872–78, Mauritius 1841, and again in 1872, Java 1882, Antigua and others of the British West Indies 1895–99. Some of these visitations have been due to unknown causes, others have been designated as rind disease, sereh, or root disease. As a matter of fact most of them come under the head of deterioration. In a considerable number of these epidemics the Otaheite or Bourbon cane has been involved.

One of the most striking instances of this kind was the running out of this variety over a number of years (1895–99) in Barbados, Antigua, and others of the British West Indies. This has always been ascribed to the rind disease, and was satisfactorily checked by the substitution of new and more resistant varieties, a measure which has served to overcome the various epidemics as well.

During recent years the Lahaina cane of Hawaii (probably the same as the Otaheite) has been failing in certain districts, giving rise to what is known as the "Lahaina trouble." Various agencies have at one time or another been held responsible, top-rot, stellate crystal fungus, poor drainage, senility, and others but the actual cause is still obscure. New varieties and possible changes in cultivation and fertilization seem to be the control measures now being tried.

It is apparent that the system which had universally prevailed in all cane countries, at least until serious diseases have appeared, of growing one variety to the practical exclusion of all others, has resulted in all of them, though at different times, in a deterioration of the plants so decided as to assume the proportions of an epidemic. In each instance secondary factors, such as rind disease and other fungi, have appeared, so that the visual symptoms have varied over a considerable range, though the underlying causes were the same.

Rind disease.

Principally because of resemblances to the "rind" disease epidemic of the British West Indies particular attention was given to a search for this disease. The drying and shrinking of the stalks from the top downward with consequent death of the leaves and the final production of the innumerable conidial masses was conspicuously absent, much less being found in mottled fields than occurred in normal fields elsewhere. Not even in abandoned third phase fields could *Melanconium* be found, except in isolated cases. Near Camuy a field of Rayada of nearly fifty acres was discovered which it had not been possible to cut for the mill, and which was being left until the following season. Not a sign of mottling was present, but it was fast approaching total loss due to rind disease.

No evidence has been obtained to bear out the theory that *Melanconium* may be present in stalks which appear normal.

Gumming.

The question will arise in the minds of many as to whether or not mottling is connected with gumming disease (*Bacterium vascularum*) of sugar-cane, if not in fact that identical disease. A summary of the symptoms of this latter disease, practically none of which apply to mottling, should clear up this ponit. Quoting Dr. Erwin F. Smith (25), "The most conspicuous signs of this disease (gumming) are dwarfing, striping of the leaves, drying of the tops, decay of the heart (terminal bud), and the appearance of a yellow

slime or gum in the bundles of the stems and leaves. Many of the bundles are also stained red."

CONTROL.

Particular attention naturally has been given to the very important subject of control, and a number of popular accounts (33, 34) of the disease have dealt largely with this topic. It has been necessary to modify from time to time the measures recommended as further data on the course and nature of mottling became available, but with the definite knowledge now at hand it is possible to outline a satisfactory system for control.

It will be noted that it is control measures and not remedies or a "cure" that it is proposed to discuss. It has at all times been apparent to those working on the problem that a remedy was out of the question, although this has been the persistent demand of many of the cane growers. Much time and effort have been expended in attempting to combat theories based on such views and to make clear the fact that a plant once it is attacked remains so, and that there is but one thing to be done with it—destroy it to prevent spread of infection.

Several instances have been reported of individuals who were offering remedies for sale. It was never possible to obtain samples of these products nor definite information concerning them nor does it appear that any results were obtained from their use, if indeed they were ever used.

A suggestion was made in last year's report that where the percentage was not too high, diseased stools should be dug out and destroyed. At the time the idea in mind for the most part was to prevent any chance of diseased material being taken for seed. When, however, the infectious nature of the disease became so clearly evident, an experiment started for studying the spread of the disease (already described) was changed to one for eradication. The chart (Fig. 2) will show the number of stools dug from the field up to November first. Since that time several additional scoutings have been made and a considerable number of newly diseased stools removed. In the beginning of this work mottled stalks only were removed in order to ascertain whether the disease would appear later in other portions of the same stool. This was what actually occurred in all cases, so that it can be stated that in attempting eradication work entire stools should be removed no matter now few stalks actually show mottling. This partial removal complicated the task of eradicating the disease in the field in question, as did

the fact that it had been permitted to spread unchecked over one full season However, results in the main have been satisfactory.

Some attempts on a field scale have been made to eradicate the disease by digging out of affected stools, but the difficulty of securing the united or continuous effort necessary to insure the success of an undertaking of this nature has made its thorough carrying out almost impossible. Apparently only the prospect of complete ruin can force this action.

One specific case has been under observation for the past two seasons where work of this kind has been in progress. This is a *finca* of about 500 acres situated in a badly infected district. In addition to digging out diseased stools at the time the cane is about two feet high, the best of culture including seed selection, liming, fertilization, deep plowing, and similar measures have been practiced. The white cane has been eliminated and the hardier Rayada and Cavengerie canes are being used. The fields composing this tract are contiguous on two sides to other cane fields which have been given ordinary care only and are badly diseased, so that the whole constitutes a severe test of the eradication proposition. Results have been very favorable and form an object lesson of what could be accomplished by united action.

The value of seed selection with elimination of seed from diseased stalks should not need more than passing mention because of its already demonstrated relation to control. All experiments and field observations prove absolutely that diseased cane always results from diseased seed, hence the vital necessity of eliminating it. This has been ignored by many of the growers or at least not thoroughly attended to.

There is of course a difficutly experienced at this point because of the fact that seed pieces may be diseased without giving outward signs once the leaves are removed. Cankered pieces could of course be readily eliminated. This problem brings up again the advisability of cutting out mottled stools before the cane reaches any great height. Some infection will doubtless occur after the cane has closed in and is of such a height as to make it inadvisable to scout the fields further, but the amount would be reduced to a minimum.

The ultimate solution of the problem lies in the finding of immune or at least strongly resistant varieties as is the case with so many tropical plant disease problems. Several of the seedlings produced by the Insular Experiment Station and tried out in infected

[1] The plan of eradication proposed in Circular 14 of the Insular Experiment Station, Río Piedras, P. R., has been widely adopted on this Island.—EDITOR.

areas, give promise but certain results can only be secured by trials carried out over a series of years. Since a disease similar if not identical to the mottling, occurs in Java and Hawaii and is there kept in check by resistant varieties it is not at all improbable that some of these will prove of value in Porto Rico. Lyon in this connection suggests the striped Mexican (which seems to be the same as the striped or Rayada of Porto Rico), D–1135, and Badilla, all of which are reported "as very resistant to yellow striping."

Even though it has been shown that cultural factors are not directly concerned with the presence or absence of mottling or its relative virulence, it must not be lost sight of that these are still matters of vital importance to the cane growers, and should be given constant attention since other diseases are always present in Porto Rican fields, and may easily cause serious damage if neglected. Improved cultural methods will give greatly increased yields in spite of the presence of the disease and so help to overcome the losses due to its occurrence.

The measures recommended then for control may be briefly summed up as follows:

Seed should not be taken from diseased stools. Certain fields should be assigned to seed production and a determined effort made to clear of mottling by digging out any stools which become infected.

Seriously diseased fields or those where the returns will be so reduced by the presence of the disease as not to cover expenses should be plowed up. Because of the great number of volunteer diseased shoots that would appear, replanting immediately should be done only in case of necessity, and then only after very careful preparation of the soil.

Where the amount of disease present is not over a small per cent of the total number of stools, an attempt should be made to eradicate the disease by digging out diseased stools, using care to get out all the rhizome or underground portion of the plants. Such holes can be replanted since there is no evidence that infection is spread through the soil. The dividing line between fields to be ploughed up and those to be "rogued" must be determined by each individual grower, since it involves the economic side of the situation.

In planting the hardier canes should be used and whenever possible new varieties should be given a trial.

SUMMARY.

A serious epidemic of cane disease has been raging in Porto Rico for several years and continues unabated.

While various names have been applied to it, mottling disease is the preferred name.

The disease first appeared in the northwestern section of the Island (Arecibo-Aguadilla) and has spread rapidly eastward, until only a portion of the east and southeast coast regions remain uninfected. Indications point to continued progress of the disease. Upland fields have as a rule been the most severely attacked.

Losses to date are estimated at $2,500,000. Losses are produced by a reduction in tonnage. Difficulty is often experienced in handling the juice of diseased canes in the mill.

Observations and experimental plots demonstrate that the disease spreads by other means than infected seed pieces.

The mottling disease has been found on several varieties in Santo Domingo where is was not epidemic. One infection area has been reported from St. Croix.

The white (*Blanca*) or Otaheite was first seriously attacked, but in succeeding seasons the Rayada and other native types have succumbed. The numerous foreign varieties, mostly seedlings, vary greatly in their behavior, certain ones being very susceptible, while others give promise of proving satisfactorily resistant. Some of the station seedlings are promising.

The disease is characterized by a mottling of the leaves, followed in advanced stages by a stunting of the entire stool and the presence of gray, sunken lesions on the stalks. The appearance of the mottling varies greatly with the variety infected. Approximately a three-year course is followed, the disease becoming more pronounced with each succeeding ratoon, and ultimately causing death of the affected stools. No other hosts have been found.

A field to field survey has confirmed the opinion held that nature of the soil, years in cane, method of preparing the land, drainage, and other cultural factors have no direct relation.

Field and plant house observations and experiments demonstrated that fertilizers, liming, seed treatment, manner of disposing of the trash, soils, moisture content of soil, and all similar points have no direct influence. There is an accumulative effect in successive ratoon crops.

It has not been possible to transmit the disease artificially.

Chemical tests of the juice do not show any abnormal glucose ration or any constant difference between the juice or normal and diseased canes.

Fungi and bacteria are not associated in any way as causal agents, either on the leaves or stalks. The cankers are a result of

the general weakening of the plant, and are not primarily caused by fungi, which may, however, invade them later on in their development.

Planting tests of stalks showing leaves mottled in part only demonstrate that the infectious principle is present in all parts of diseased plants.

The disease is transmitted by means of diseased seed pieces, but has also some other means not yet apparent. It does not persist in the soil and infection is aerial. Certain insects are suspected as carriers.

The disease is considered to be an infectious chlorosis due to a virus or ultramicroscopic organism. The degeneration theory previously advanced is completely abandoned.

Lyon of Hawaii suggests that the yellow striping disease of Java and Hawaii is the same. There are many points of similarity, but lack of literature and authentic material of the yellow striping makes a final conclusion undesirable at this point.

Sereh is an infectious cane disease of Java which has been epidemic at times. It resembles mottling in some respects but is sufficiently distinct. The causes of the two diseases are thought to be of the same nature.

A comparison of symptoms, manner of transmission causes, and related points is made between mottling and the curly-top of beet, tobacco mosaic, spinach blight, peach yellows, cucumber mosaic, potato mosaic and other abnormalities of potatoes, all of which it is thought are due to similar causes, *i. e.*, ultramicroscopic organisms.

There are a number of diseases or abnormalities of cane which have been or might easily be confused with mottling. Deterioration is a phenomenon due to long continued cultivation of one variety, to poor cultivation, to unfavorable weather or other non-parasitic conditions. It is marked by a yellowing of the leaves and stunting of the stools.

There is a form of root disease due to the action of parasitic fungi which have not yet been clearly differentiated. Chlorosis is a yellowing or whitening of the leaves of entire stools in limited areas due to inability of the plants to assimilate sufficient iron in the presence of an excess of lime in the soil. Yellow spotting is characterized by spots on the leaves resembling those of mottling but more yellow in color. The condition is due to lack of cultivation or drouth.

Certain varieties of cane are subject to long white stripes on the leaves which are of the nature of chimeras. Under green-house

conditions mites produced markings on the leaves almost indistinguishable from those of mottling.

Sun burning and possibly surface-growing fungi produce gray blotches on exposed stalks.

A very serious epidemic of cane disease occurred in Porto Rico in 1872–80 and was studied by a royal commission without the cause being ascertained. In some respects it resembled the mottling but cannot be considered to have been that disease. It was controlled by natural factors and the use of resistant varieties. A later phase of the same situation was shown to be due to white grub attacks.

There have been minor epidemics, and one in particular of rind disease, but it has not been possible to trace any earlier occurrence of mottling, indicating that it is a recent introduction.

There have been serious outbreaks of cane disease in practically all other cane-growing regions of the world, including Java, Mauritius, and the West Indies. The mottling disease has no connection with either the rind (*Melanconium*) or gumming (*Bacterium vascularum*) diseases.

Control lies in the use of disease-free seed, and the elimination of diseased cane either by plowing badly attacked fields or by digging out diseased stools. United action on the part of all cane growers is necessary. The more resistant varieties should be used to the exclusion of the very susceptible types, and continued search made for varieties still more resistant or even immune.

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